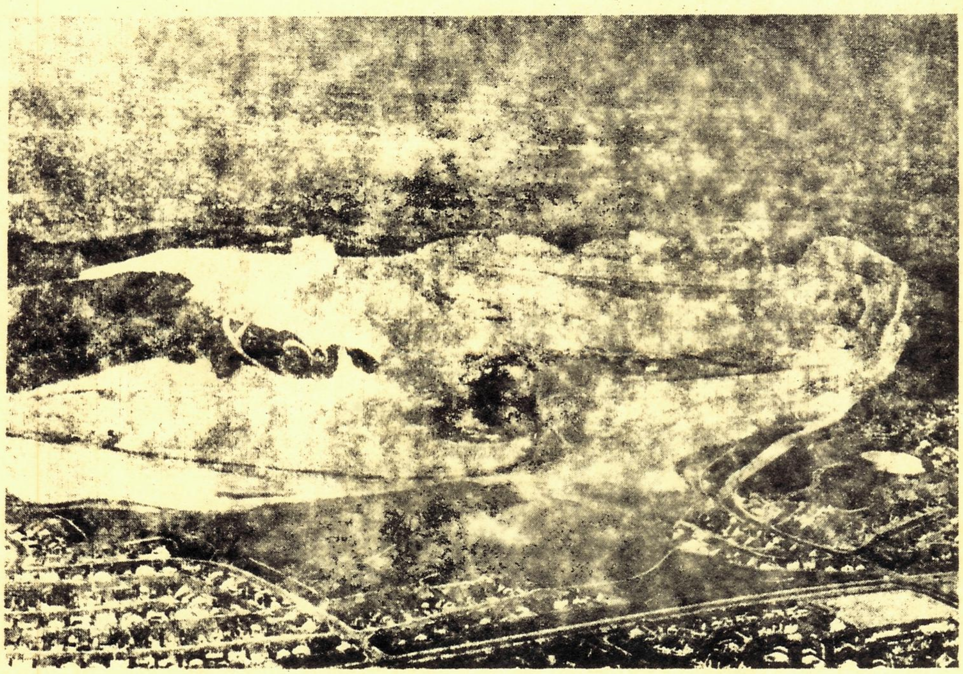
BKK LANDFILL ODOR STUDY



City of West Covina

EUTEK INC.
process
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and
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EUTEK® INC.
process development and engineering
1828 TRIBUTE ROAD, SUITE H • SACRAMENTO, CA 95815 • (916) 929-2003

BKK LANDFILL ODOR STUDY

FINAL REPORT

Prepared for

City of West Covina
Development Services
1444 West Garvey Avenue
West Covina, CA 91790

February 27, 1981

80-11-01

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City of West Covina
Development Services
1444 West Garvey Avenue
West Covina, California 91790

ATTN: Mr. Michael L. Miller
Director, Development Services

RE: BKK LANDFILL ODOR STUDY
FINAL REPORT

Dear Mr. Miller:

We are pleased to submit herewith the Final Report on the BKK Landfill Odor Study. This report represents the consolidation of the First and Second Interim Reports. In addition, the results of the evaluation of the odor reduction due to additional gas recovery wells and the summarization of the extensive micrometeorological data base have been incorporated in this report. In short, this Final Report represents a complete document on the results of the entire December - January odor study. It serves not only to meet the City Council directive of a scientific measurement of the BKK Landfill site odor emissions but also provides a basis for effective future odor control planning for the BKK Landfill. Many landmark findings regarding sources of and alternatives for control of landfill odors have been made in the course of the study and have been fully documented in this report.

The primary objective of the BKK Landfill Odor Study was to determine using scientifically valid measurement procedures if improvements in landfill odor control occurred during the course of the study. Specifically, the following measurements were to be made:

1. Measurement of reduction in odor emissions due to control or elimination of acid dump wells.
2. Determination of odor reduction resulting from gas recovery system installation and operation.

In addition to these determinations, evaluation of two large area odor control measures were also to be made:

1. Barriers
2. Water aerosol

Based on the results of the on-site measurements of odor emissions and the effectiveness of the odor control measures an assessment of odor risk was to be made to determine an effective odor control plan for the BKK Landfill. Odor risk is defined as the number of days annually in which the downwind odor concentration exceeds a specified level. An acceptable level of odor risk, mutually agreed upon by the public surrounding a facility and its management, is typically 1 to 5 distraction threshold odor concentration (5 ou/cf) events annually.

As discussed in this report all study objectives were met except that concerned with elimination of the acid dump wells. The use of these wells was discontinued prior to the initiation of the study and it was not possible to directly measure the consequent odor reduction. BKK Corporation instituted other operational controls prior to the study start-up which may have resulted in additional odor reduction. These operational controls were:

1. Filling, grooming and maintenance of landfill slopes to close surface cracks and fissures.

2. Rejection of odorous substances.

It is recommended that these operational controls be continued.

The gas recovery system was found to be an efficient means of odor control when properly designed, installed, and operated. Raw landfill gas odor concentrations ranged from 100,000 to 500,000 ou/cf. Combusted gas odor concentrations ranged from 75 to 150 ou/cf for a 99.9% reduction in odor concentration. Migrating landfill gas discharged at the landfill surface at odor concentrations measured as high as 10,000 ou/cf. When a new gas recovery system was put into operation in the last week of the study, the highest surface odor concentrations in its vicinity were reduced 90-98% with a few exceptions.

To achieve its full odor control potential, gas recovery must be carefully designed, installed and operated to achieve:

1. <u>Maximum recovery of migrating gas in the recovery area.</u>

    a. The recovery wells and collection lines, operating under partial vacuum, must be properly designed to achieve uniform withdrawal throughout the area.

    b. Lines and wells must be properly sealed to prevent access of extraneous air into the system.

    c. Withdrawal rates must equal or exceed landfill gas production rates for the recovery area.

2. Fail/Safe Prevention of Raw Landfill Gas Releases.

On several occasions throughout the study gas recovery collection lines were broken with consequent release of raw landfill gas. On one such occasion odor concentrations in excess of 50 ou/cf were measured in downslope residential areas. Such high odor concentrations cause extreme psychological stress.

To achieve these objectives it is recommended that current plans for gas recovery at the BKK Landfill be fully implemented with follow-up surface odor emission monitoring to insure that maximum recovery of migrating gas in the recovery area is achieved.

Relative to the odor emission rates measured during December (Median: 48×10^6 ou/min) the odor risk assessment indicated that an odor emission reduction of 97 to 99% would be required to reduce odor risk to acceptable levels. Implementation of full gas recovery with follow-up surface odor emission monitoring may accomplish the required degree of odor reduction. If it does not, several other mitigation measures could be implemented, one-at-a-time, until the odor risk has been reduced to acceptable levels. These possible subsequent measures, in the recommended sequence, are:

1. Design and construct earthen levees with barriers to channel and redirect cold downslope drainage air away from downslope residential areas. It is estimated that this measure could further reduce downslope complaint conditions by 76%.

2. Design and construct a peripheral water aerosol system to significantly increase the relative humidity (RH) of the downslope drainage air. Unfortunately a quantitative estimate of expected odor reduction can not be assigned to this measure. When the water aerosol system was under evaluation, ambient air RH was high, frequently above 90% thereby minimizing the impact of the system in reducing downwind odor concentrations. Nevertheless, the following points are worth noting:

   a. On several occasions increases in RH were measured in spite of high ambient air RH. This suggests that the water aerosol system was an efficient means of increasing RH under landfill conditions.

   b. High RH results in less severe temperature inversions and a lowered frequency of critical odor "puff" transport conditions.

c. With all other monitored micrometeorological variables similar for December and January, there was significant increase in RH in January over December levels. There was also a 73% reduction in confirmed and measureable odor complaints in January relative to December. While some of this reduction might be ascribed to the operational controls implemented by BKK Corporation, the increased RH must be given credit for the balance. In fact, during high RH conditions in early December no odor complaints were recorded.

Should the need for implementation of this measure arise, it is recommended that further evaluation of a large scale system be carried out under low ambient air RH conditions (September-November) to develop design criteria for a complete system.

3. Evaluate and install micrometeorologically (MM) controlled wind machines along periphery of landfill.

This is the most "mechanical" of the recommended mitigation measures and has the greatest potential for interfering with landfill operations. However, if implemented properly with measures 1.) and 2.) above, it has potential for reducing downwind odor concentrations by an additional 67%. Its effectiveness in this regard has been documented by other EUTEK, INC. studies under the very calm conditions responsible for complaint odor concentrations downslope of the BKK Landfill. Pilot testing of the MM controlled wind machines would be required prior to system installation to insure proper orientation and placement to achieve vertical mixing across barriers without attendant noise problems.

Through prudent implementation of the above step-by-step odor mitigation program in conjunction with continuation of measures already undertaken by BKK Corporation, an acceptable level of odor risk can be achieved for the BKK Landfill. In time, this should establish the BKK Landfill as a good neighbor to the surrounding residences.

The alternative of site closure is both less effective and potentially counter-productive in accomplishing the degree of odor reduction necessary to achieve an acceptable level of odor risk.

It has been our sincere pleasure to work with you and the involved staff of the City of West Covina and to have had your full support and cooperation. A study of this scope and depth could not otherwise have been accomplished under the circumstances. Through your courage, perseverance, and professional performance, many landmark findings have been scientifically established which will go beyond the immediate problem and greatly aid others facing similar circumstances.

We are also indebted to the staff of BKK Corporation for their always helpful and supportive attitude and their direct assistance in many cases. A very difficult job ran much more smoothly than one could reasonably expect due to their helpful advice and assistance. On top of it all, the landfill continued to be operated in an exemplary fashion throughout the study period.

We are prepared to answer any questions you may have regarding this report and would be pleased to further discuss any points of special interest to you.

Respectfully Submitted,

EUTEK, INC.

George E. Wilson
Project Manager

Terry W. Schroepfer
Project Engineer

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I. INTRODUCTION AND PROBLEM STATEMENT

INTRODUCTION

On Monday evening, 27 October 1980, the West Covina City Council instructed the City staff to scientifically measure odor emissions from the BKK Landfill. This directive was prompted by widespread citizen complaints concerning nuisance odors attributed to the landfill site. A 90-day timetable was established during which measurable reduction in odors emitted from the landfill site were to be quantitatively established by this scientific measurement procedure.

The BKK Landfill site is presently the only Class I solids disposal site operational in the Southern California area. As such, it is the only site in this area which can accept liquid and toxic wastes. Its continued operation is, therefore, important to the many public and private entities generating these wastes and to the public whose best interests are served by careful control of such waste materials.

Nuisance odor complaints have been associated with the BKK Landfill for some time. In an effort to mitigate nuisance odor conditions, BKK Corporation contracted with the University of Southern California (USC), Environmental Engineering Department, to sample air quality at several locations in the landfill and in the surrounding area. A report summarizing the results of this study was submitted to BKK Corporation in September 1980.(1) The study did not attempt to quantitatively measure mass emissions from the landfill nor did it quantitatively measure odor. Concentrations of volatile compounds in the air were determined. Odor was attributed primarily to hydrogen sulfide which was measured at levels above the minimum detectable threshold odor concentration (MDTOC) at some locations surrounding the landfill. The USC study concluded that containment and scrubbing of off-gases from the sulfuric acid disposal wells should control the primary source of hydrogen sulfide.

In responding to the City Council's instructions, Mr. Michael L. Miller, Director, Development Services, City of West Covina, requested that EUTEK, INC., review the conditions pertaining to the BKK Landfill odor emissions. EUTEK, INC., was asked to develop a proposal for a work effort which would scientifically measure odor emissions from the BKK Landfill such that a definitive conclusion could be drawn regarding reductions in such odor emissions over the 90-day period.

EUTEK, INC., submitted a proposal for the BKK Class I Landfill odor study to Development Services of the City of West Covina on 4 November 1980. In their regular meeting on 10 November 1980, the City Council of the City of West Covina authorized initiation of the proposed work plan at the proposed Level A effort. EUTEK, INC., was requested to proceed immediately on Phase I, Mobilization, on Wednesday, 12 November 1980. Formal contract documents were completed on 10 November, 1980.

This report will describe efforts undertaken and results measured during the course of the study.

PROBLEM STATEMENT

Odor complaints are received by the City of West Covina Police Department. They are formally logged and forwarded to Development Services. Based on the location of most of the complainants and confirmation of detectable nuisance odors by followup City staff teams, Development Services has been able to identify four primary locations surrounding the BKK Landfill at which most nuisance odor conditions occur.

1. "M Streets", southeast landfill boundary - Most nuisance odor conditions have been noted to occur in this area. Strongest odor concentrations have been noted at the intersection of Miranda and Marcella streets.

2. <u>"L Streets", south landfill boundary</u> - The next most frequent location of nuisance odor conditions have been noted in this area, particularly on Lynn Court, immediately adjacent to the south landfill boundary.

3. <u>"Aroma Street", north landfill boundary</u> - Odor concentrations at nuisance levels are sometimes noted along this residential area.

4. <u>"Hidden Valley and Casa Linda", northeast landfill boundary</u> - Nuisance odor concentrations are sometimes detectable in this area.

It should be noted that all of the above locations are localized low points in topography in which cold air and odorants can concentrate during the evening hours.

The complex wind patterns at the BKK Landfill further complicate the definition of odor emission conditions. It is not uncommon to observe widely varying wind directions at various locations surrounding the landfill boundary. While the writer was visiting the landfill site with the Director of Development Services, wind was out of the southeast in the M Street area whereas a few minutes later the winds were out of the northeast on Aroma Street.

Located as it is in a hilly area, complex dispersion conditions will characterize transport of odors from the landfill source to downwind residents. Any attempt to monitor downwind odor concentrations from the site without accounting for the effect of varying dispersion would eventually lead to questions concerning what source odor emission rates actually existed.

Not the least ot the factors lending to the complexity of a clear definition of odor emissions from the BKK Landfill is the nature of a landfill solids disposal operation itself. Odor sources are widely distributed and will exhibit variable odor emission rates. Disposal locations are continually changing throughout the site. Site topography is undergoing continual change. Finally, climatic conditions will affect both odor emissions and disposal site locations.

A definitive and quantitative measure of odor emission rates from a large area landfill site such as the BKK Landfill must account for the many variations in source odor emission rates, variations in micrometeorological conditions at the site, and the variations that can occur in dispersion of odors traveling from the landfill source to a downwind residence.

Effective and reliable resolution of large area odor problems generally requires more than the quantitative measurement of odor emissions. Mitigation measures specifically designed for large area nuisance odor problems should also be considered if the greatest probability of successful resolution is to be achieved. Mitigation measures for large area odor emissions are concerned with modification of the atmospheric sublayer micrometeorology and/or modification of site dispersion conditions to prevent or mitigate the occurrence of high concentrations of odorants adjacent to the ground level. The effectiveness of these measures for reducing downwind odor concentrations can best be evaluated in conjunction with quantitative measurement of landfill site odor emission rates.

II. STUDY OBJECTIVES

The primary objective of the BKK Class I Landfill odor study was to determine if improvements in landfill odor control occurred during the course of the study. Measurement of such improvements would be based upon scientifically valid techniques of odor measurement. Specifically, the following measurements were to be made:

1. Measurement of reduction in odor emissions due to control or elimination of acid disposal wells.
2. Determination of odor reduction resulting from gas recovery system installation and operation.

In addition to these determinations, evaluation of two large area odor control measures were also to be made:

1. Barriers
2. Water aerosol

Based on the results of on-site measurements of odor emissions and effectiveness of odor control measures, an odor risk assessment was to be made to determine the required degree of control at the BKK Class I Landfill to insure acceptable odor conditions.

III. SCOPE OF ODOR CONTROL ENGINEERING STUDY

The odor control engineering services for the BKK Landfill odor study involved seven separate study tasks. These study tasks and the schedule of implementation have been shown on Figure I.

In addition to determination of quantitative odor emissions from the BKK Landfill site over the 90-day period, the study also evaluated the effectiveness of large area odor emission mitigation measures for modifying both site micrometeorology and dispersion.

TASK I. MOBILIZATION

Suitable odor subjects were screened, calibrated and trained. All instrumentation concerned with olfactometric, micrometeorological, and odor transport measurements were leased, performance checked, and calibrated. Supplies for supporting each of the work phases were purchased and quality control tested.

Definitive study procedures were set up during the mobilization period. These were reviewed with City and BKK Corporation staff on Tuesday, 18 November, 1980 to insure that study procedures would not interfere in any way with landfill operations and in order to insure maximum cooperative work effort with the involved citizenry.

TASK II. HISTORICAL ODOR COMPLAINT ANALYSIS

This task concerned statistical summarization of the historical odor complaint record attributed to the BKK Landfill. The analysis serves to identify seasonal and diurnal trends in odor complaints. Mapping of complainant locations and relative frequency of complaints serves to identify the relative sensitivity of areas surrounding the BKK Landfill to odor emissions.

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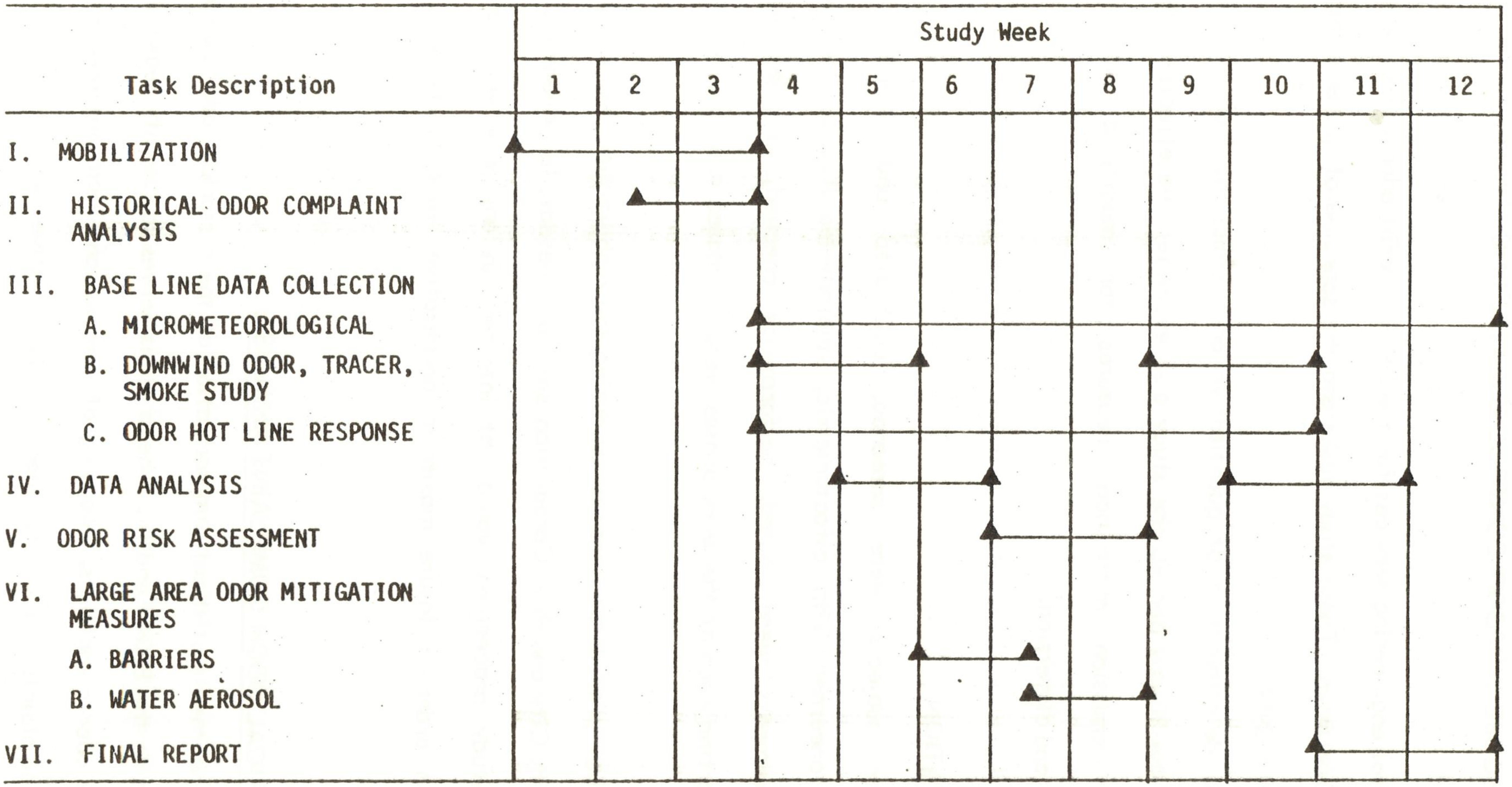


FIG. 1 BKK LANDFILL ODOR STUDY SCHEDULE

TASK III. BASELINE DATA COLLECTION

The baseline data collection task represented the heart of the study to quantitatively measure odor emissions from the BKK Landfill over the 90-day period. The task was broken down into three phases: micrometeorological monitoring; downwind odor, tracer, and smoke studies; and odor "hot line" response studies.

As shown on Figure I, Task III was scheduled over two separate two-week study periods. The separation was to allow measurements before and after the USC recommended odor mitigation measures had been implemented. The two-consecutive-weeks study period is the minimum time required at this time of year to obtain a statistically signifcant number of valid measurements. Valid measurements must be made under strong sublayer inversion conditions with sufficient duration to allow unambiguous interpretation of results. At this time of year, each two-week study period should provide approximately ten valid measured conditions.

A. Micrometeorological Monitoring (three stations) - In order to define the complex wind patterns surrounding the BKK Landfill, it was necessary to maintain three micrometeorological monitoring stations around the plant boundary. One of these stations was the existing BKK weather station located above the M Street residential area. The second micrometeorological monitoring station was located above the L Street area on the BKK Landfill site. The third micrometeorological monitoring station was located on the top deck of the BKK Landfill site.

Throughout the active data gathering portions of the study, one man was responsible for maintaining all micrometeorological monitoring stations and advising downwind measurement crews as to prevailing conditions at the three monitoring stations.

In addition to measurement of wind speed and direction, absolute temperature and humidity at a fixed elevation above ground surface was measured at each of the monitoring stations. Specialized temperature gradient and counter-radiation heat flux measurements were made at the L Street location in order to define the strength of the site sublayer inversion.

B. Downwind Odor, Tracer and Smoke Studies - Based on prevailing wind drift and/or current residential complainant location, odor measurements were made downwind of the BKK Landfill utilizing the Eutek Systems Direct Reading Olfactometer (DRO). The DRO measures odor concentrations in terms of dilutions to minimum detectable threshold odor concentration (MDTOC), or equivalently, odor units per cubic foot of air (ou/cf) under carefully controlled conditions.

Simultaneous with odor measurements, ambient air samples were taken for subsequent gas chromatographic determination of tracer gas concentrations. Cylinders of inert and odorless tracer constantly discharged at known flow rates at predetermined locations within the BKK Landfill site. Through correlation of downwind tracer concentrations with tracer emission rates within the site it was possible to quantitatively estimate the odor emission rate magnitudes within the BKK Landfill site responsible for the measured downwind odor concentrations. Periodically, samples of ambient air were bagged for subsequent analysis of selected odorant concentrations.

Smoke studies provided visual confirmation of odor transport conditions. Under low wind conditions, smoke bombs were set off within the BKK Landfill in order to visually document the flow of landfill air to surrounding residential areas. These smoke studies were also used to visually evaluate the effectiveness of the large area odor emission mitigation measures.

Throughout the active data gathering portions of the study, one man was responsible for maintenance of the on-site tracer gas and smoke bombs. Two men were responsible for taking downwind tracer samples and analyzing these samples gas chromatographically. Olfactometric odor measurements with the DRO involved a three man crew consisting of the subject, operator and crew supervisor.

C. Odor Hot Line Response - Residents surrounding the BKK Landfill assisted in the quantitative measurement of odor emissions from the BKK Landfill by promptly phoning in when detectable odors were noted. The City of West Covina two-way radio system was utilized to immediately notify downwind odor and tracer measurement crews of the location of the detectable odor. The crews moved to confirm and measure actual levels of odor concentrations. Tracer gas samples were taken simultaneously in order to determine the apparent magnitude of odor emissions responsible for occurrence of detectable nuisance odor concentrations.

In addition to the odor hot line response, two meetings were held with a formal citizens advisory group. In these meetings the status of the study, its results, findings, and any suggested changes or improvements which could further assist the study in meeting its objectives were discussed.

IV. DATA ANALYSIS

As shown on Figure I, there were two separate two-week periods during which active baseline data collection was performed. Immediately following each of these periods were periods of intensive data analysis to identify the critical micrometeorological patterns, measured transport conditions, and, from these, the apparent source odor emission rates from the BKK Landfill.

Because of the complexity of large area odor emission problems, all data was subjected to statistical analysis involving frequency distributions.

V. ODOR RISK ASSESSMENT

Through additional statistical analysis, the information analyzed in the preceding tasks were used to determine the degree of odor emission reduction required to achieve an acceptable level of odor risk. Odor risk is defined as the expected number of annual odor complaint events. An odor complaint event is defined as that condition under which nuisance odor concentrations in excess of 5 ou/cf occur at the complainant location. Odor risk assessment is an essential planning tool in defining those measures required for effective odor control.

VI. LARGE AREA ODOR MITIGATION MEASURES

The USC study commissioned by BKK Corporation identified several alternatives for control of odors from specific sources. These source control measures may have little direct effect on odor emissions distributed throughout the landfill. Control of odor emissions from widely distributed sources involves measures specifically designed for large emission areas. Two such measures were evaluated in conjunction with the present study: barriers for modification of site dispersion and water aerosol modification of site micrometeorology. Evaluation of the effectiveness of these large area odor mitigation measures entailed the same measurement and analysis procedures as employed in Tasks III-V.

A. Barriers - The use of sharp edge barriers for reducing downwind odor concentrations under suitable micrometeorological conditions has been quantitatively established by tracer studies conducted for the County of Sacramento by EUTEK, INC (2). Under natural or indured wind conditions, sharp edge barriers can effect manifold reductions in downwind odor concentrations. They are particularly attractive for large emission areas in that they are relatively inexpensive to install, require little or no maintenance and upkeep, and in addition to significantly reducing nuisance odor conditions, they provide an aesthetic visual and sound barrier as well. Under ideal conditions the BKK Landfill barriers would not have to be peripheral but would be localized at those "windows" through which cold air containing high concentrations of odors flows to surrounding residential areas.

Temporary 8 ft. sharp edge barriers were installed across one of the "windows" on the south BKK Landfill boundary prior to the second two-week baseline data collection effort. Downwind measurement procedures were identical to those utilized during the first baseline data collection period. Results were compared with those without the barrier to determine the apparent effectiveness of this system for reducing downwind odor concentrations.

B. Water Aerosol - The strength of the atmospheric sublayer inversion responsible for high ground level odor concentrations is always substantially less over water surfaces. This is due both to the difference in heat capacity of water and soil, and, the effect of relative humidity in reducing the counter-radiation heat flux. Humid air will invariably show less severe temperature gradients than air without humidity.

As a consequence of severe inversions two phenomena occur which aggravate odor problems. The first phenomenon is the absence of vertical mixing due to the stability of warm air overlying colder air. Above certain critical limits, normal turbulent mixing can no longer occur within such air layers.

The second phenomenon relates to thermal diffusivity in which trace gases tend to concentrate in colder regions of air having strong temperature gradients. When heat flows up, mass flows down.

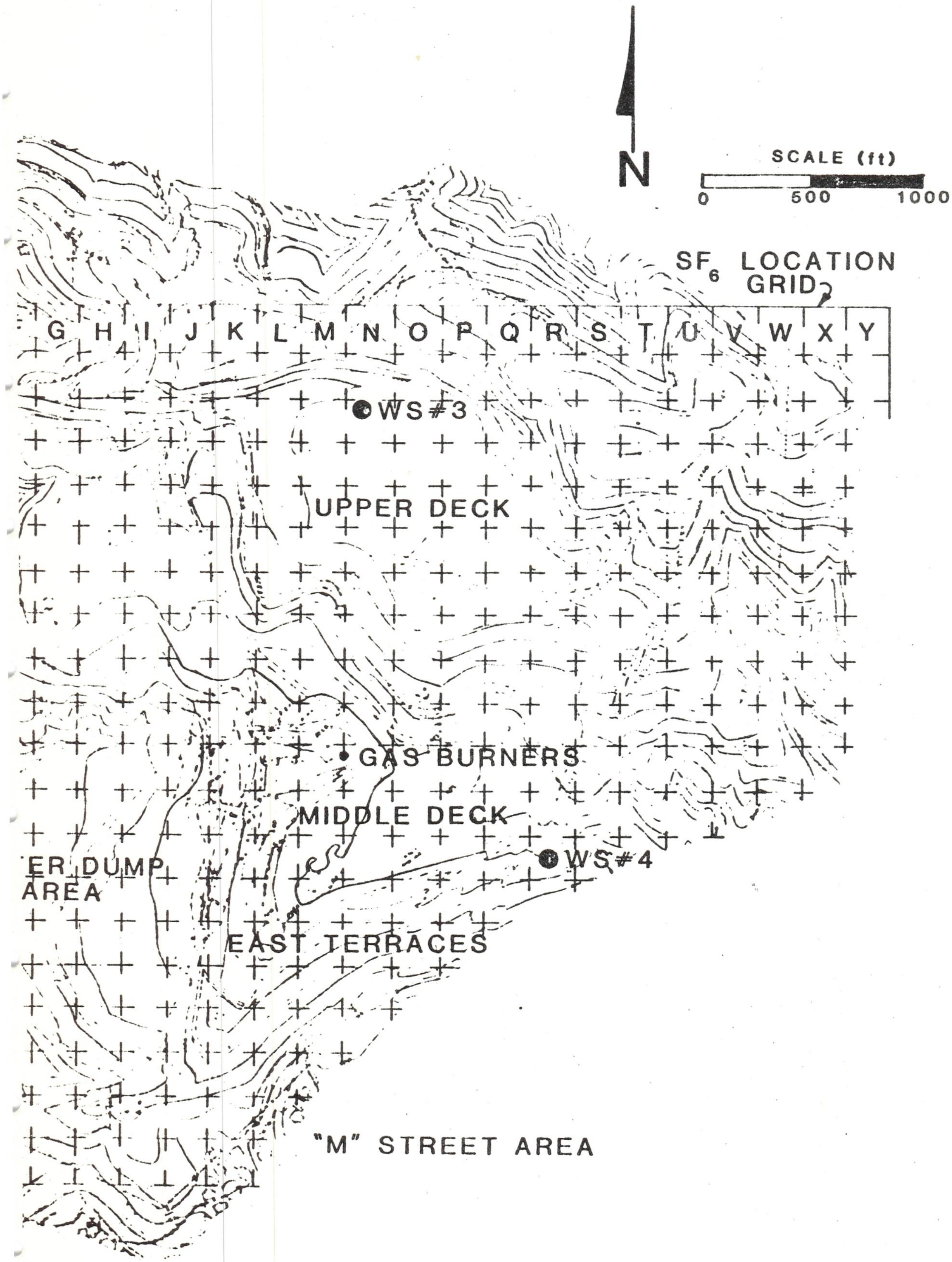
Odors emitted from a ground surface source into the coldest layers of air under strong inversion conditions cannot be effectively vertically mixed. Mixing which does occur is counter-acted by the thermal diffusivity effect. As a consequence, the strong inversion which exists over the cleared areas of the BKK Landfill provides an ideal condition for concentrating odors within the lowest and coolest air channels.

The water aerosol mitigation measure involves modifying the sublayer inversion strength through increasing the relative humidity of lower air layers. This in turn will reduce the strength of the temperature gradient within the sublayer and, in turn, reduce the tendency for high odor concentrations to accumulate in cold pockets of air.

For evaluating this mitigation measure, atomizers were distributed across the BKK Landfill site west window for a one-week evaluation. This evaluation followed that of the barriers. Like the barrier evaluation, this effort required the same downwind odor, tracer, and smoke studies as were utilized in the baseline data collection portion of the study.

VII. INTERIM AND FINAL REPORTS

As shown in Figure I, interim progress reports were prepared for review during the 6th and 11th weeks of the study. Review meetings were scheduled with the citizens advisory committee on the Thursday evening of these weeks. This final report was prepared at the conclusion of the study. All baseline data, data analysis, results, and conclusions regarding the measured changes in site odor emission rates and the need for and effectiveness of large area mitigation measures have been summarized and fully documented in these reports. This final report will serve not only to meet the City Council directive of a scientific measurement of BKK Landfill site odor emissions but will also provide a basis for effective future odor control planning for the BKK Landfill site.



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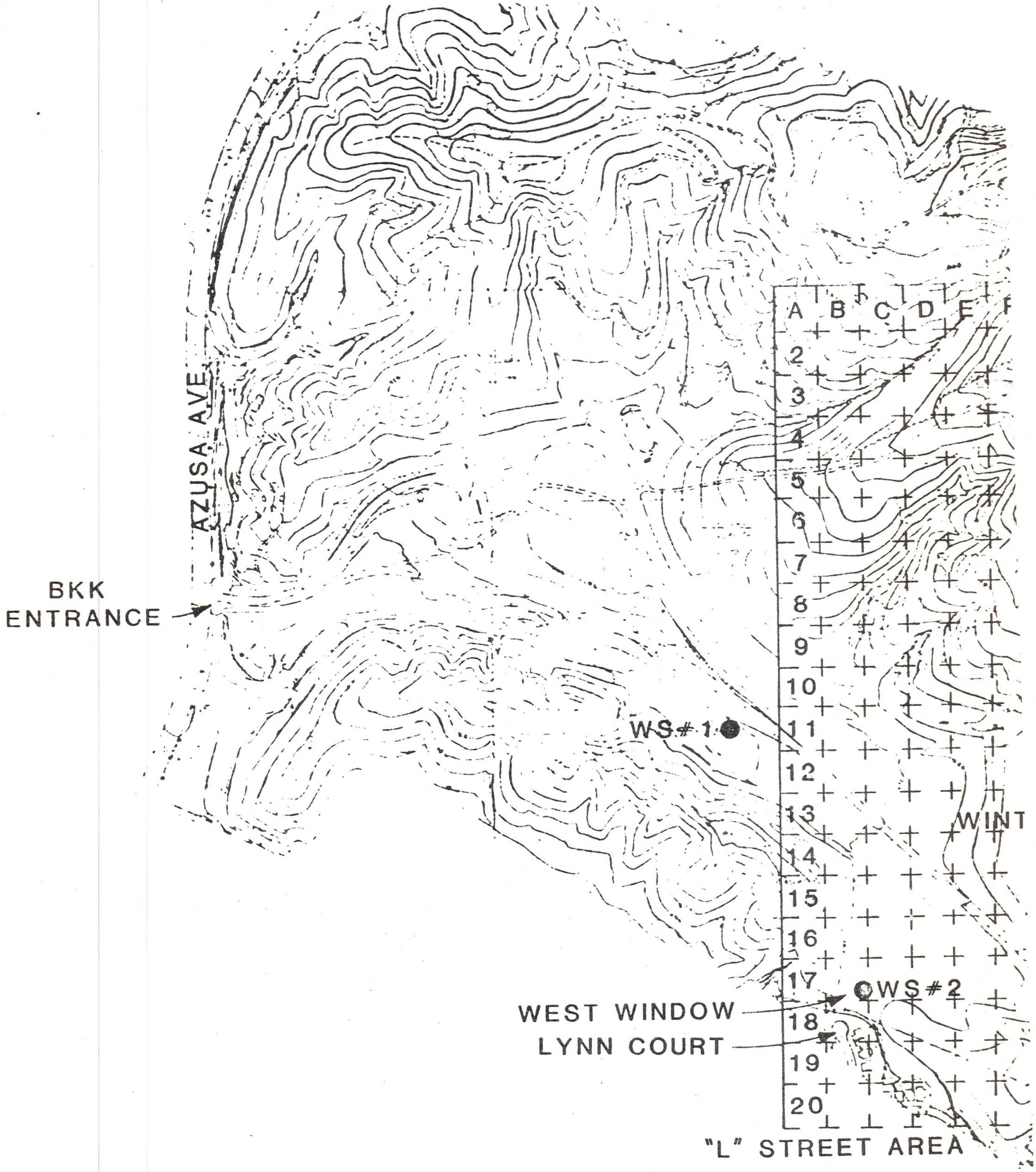
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WS#1
WINT
WS#2
WEST WINDOW
LYNN COURT
"L" STREET AREA

FIG. 2 BKK L

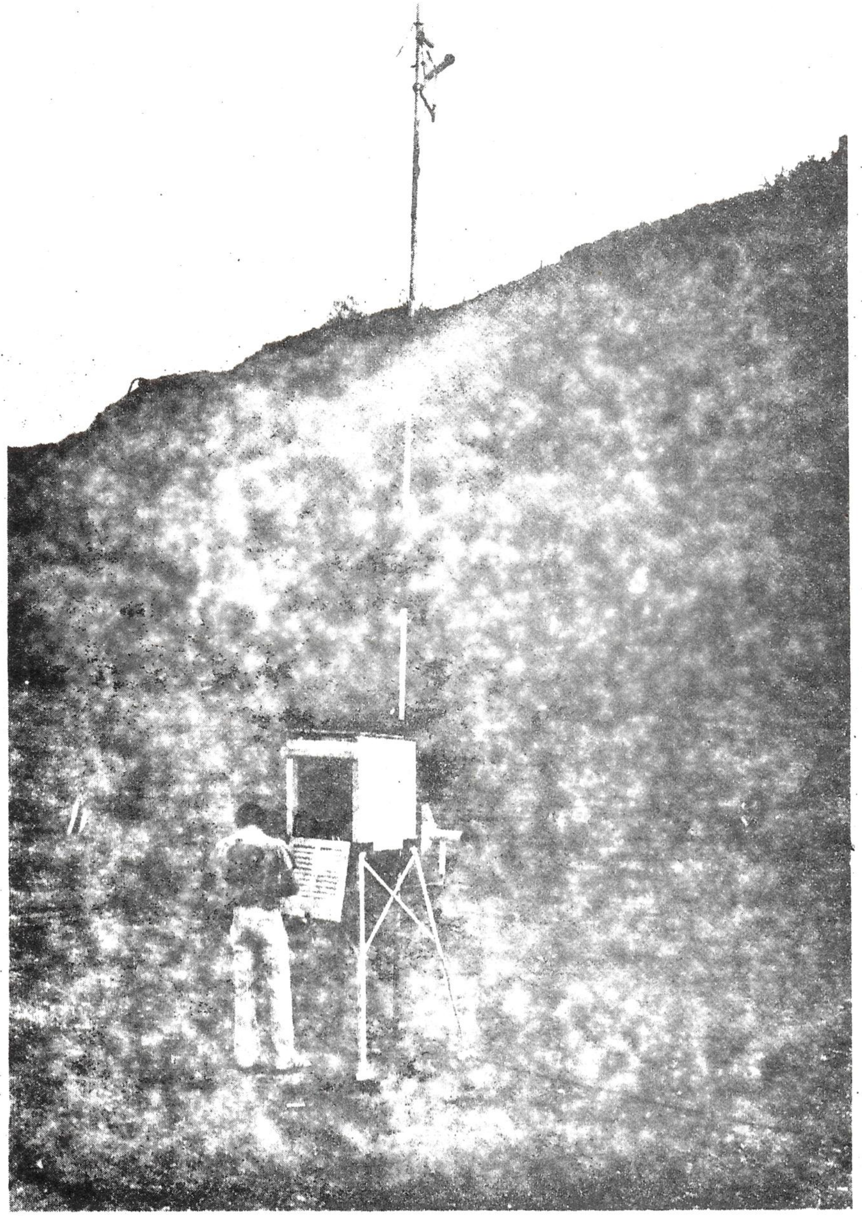
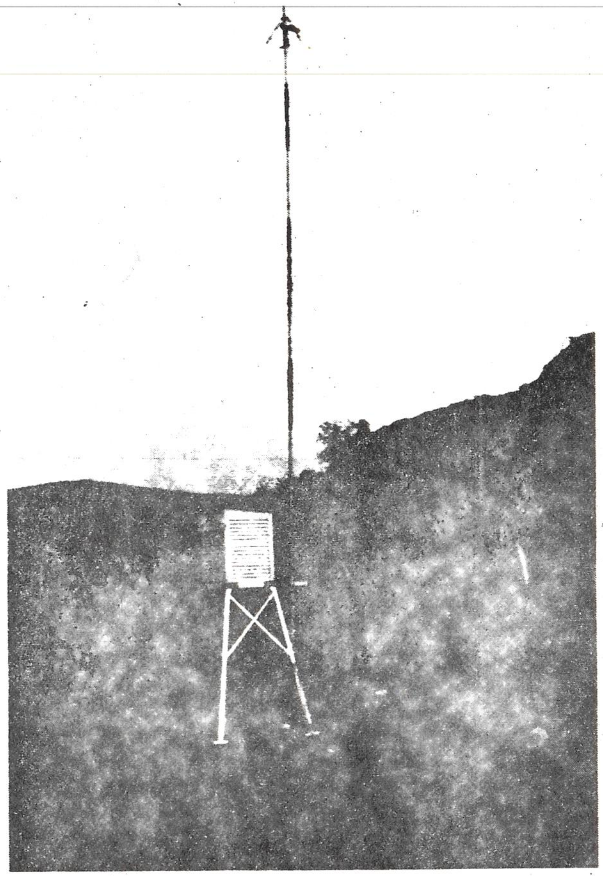
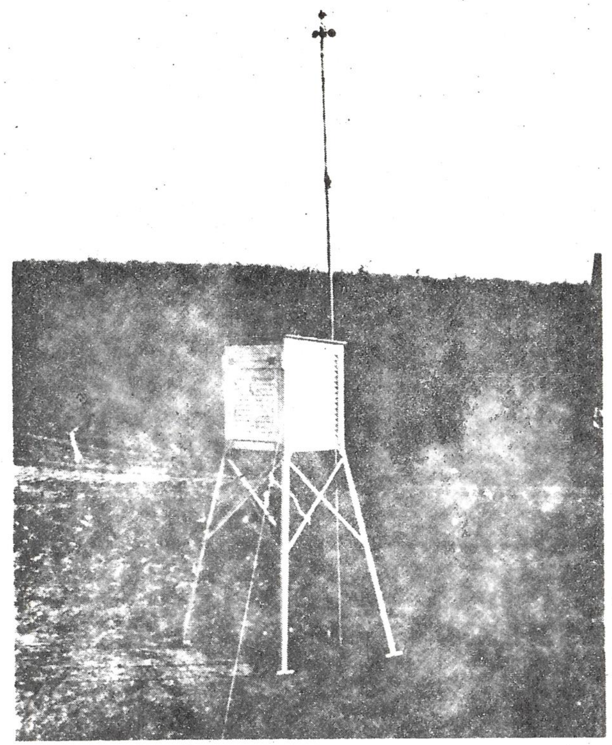


PLATE 1 WEATHER STATION 1



WS-1 (△T AND NET RADIATION)



WS-2 (WIND SPEED AND DIRECTION, TEMP. AND RH)

PLATE 2 WEATHER STATIONS

of shelters. A description of the instrumentation utilized for the micrometeorological monitoring follows.

ΔT

The ΔT instrumentation includes a tower, two thermistor temperature probes shielded by vane aspirated radiation shields, a Delta temperature translator, and a two channel dotting strip chart recorder. The translator provides a signal output for ambient temperature and ΔT. The temperature probes are mounted at 5 ft. and 25 ft. above ground level. The linearity and accuracy of the system is $\pm 0.1^{\circ}C$. The Δ T translator and strip chart recorder are shown on Plate 4 along with the net radiation recorder. The temperature probe and vane aspirated radiation shield are shown in Plates 5 and 6.

Net Radiation

The net radiation system measures and records the difference between incoming solar radiation and outgoing radiation within the spectrum of wave lengths of 0.3 to 60 microns. Net radiation is measured in order to determine net heat flux from the earth's surface. The system includes a net radiometer and a strip chart recorder. The net radiometer is shown on Plate 7. The strip chart recorder is shown on Plate 4.

Wind Speed and Direction

Wind speed and direction at WS-2 and WS-3 are recorded on a dual channel continuous strip chart recording system. Wind speed is measured by means of a 3-cup anemometer which drives an AC generator. Direction is measured with a

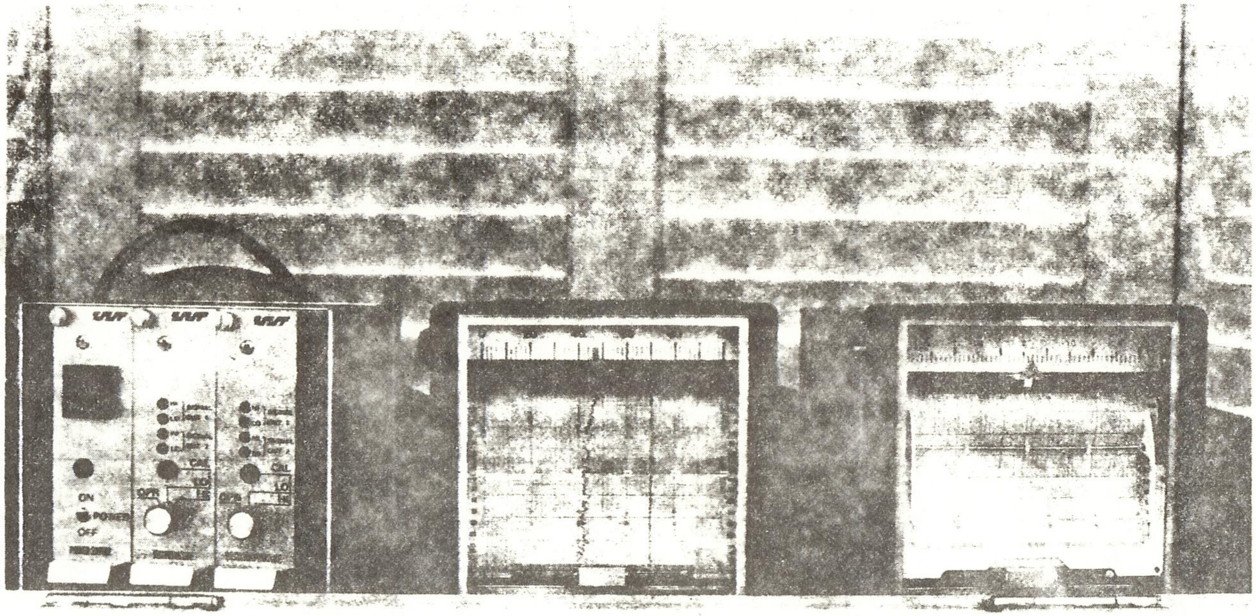


PLATE 4 ΔT AND NET RADIATION INSTRUMENTATION

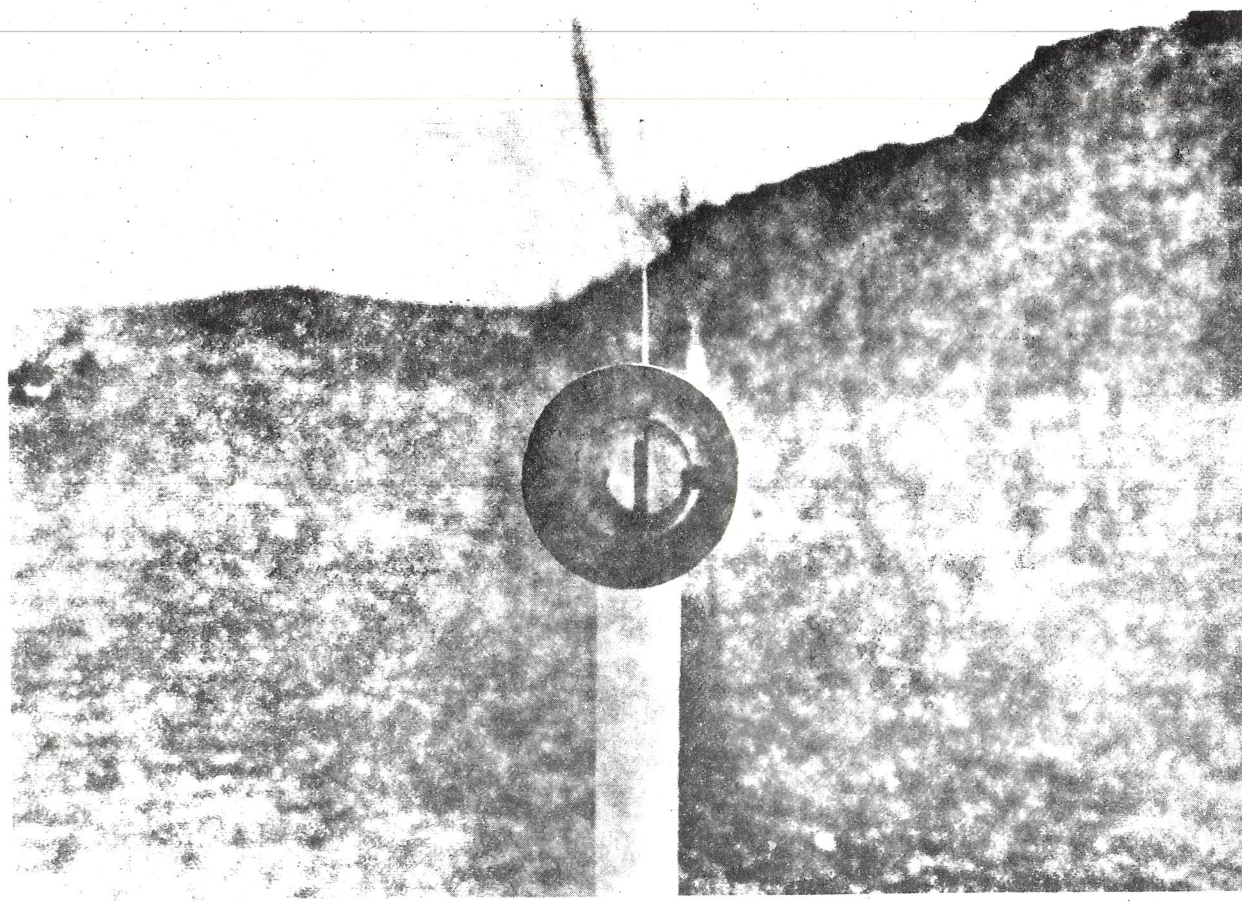


PLATE 5 TEMPERATURE PROBE INSIDE RADIATION SHIELD

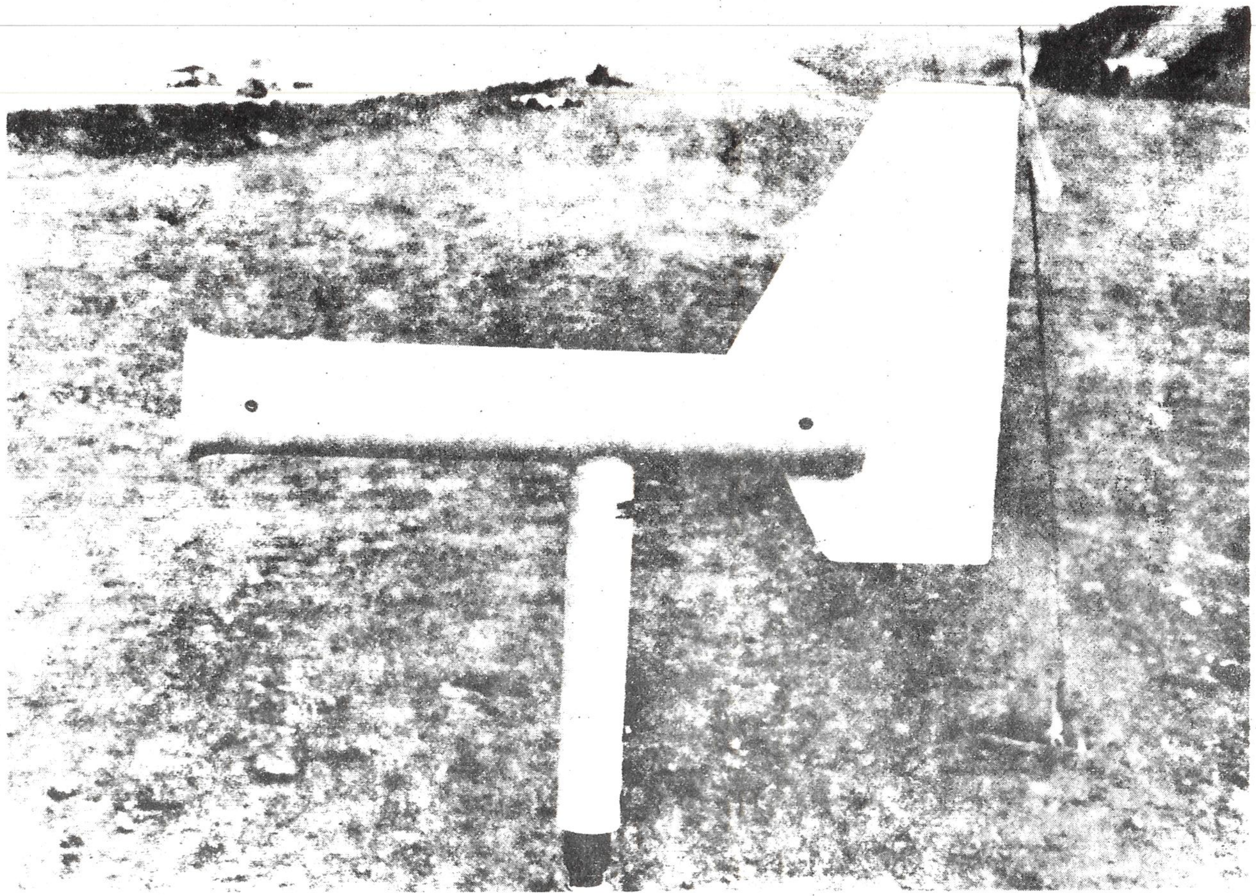


PLATE 6 VANE ASPIRATED RADIATION SHIELD

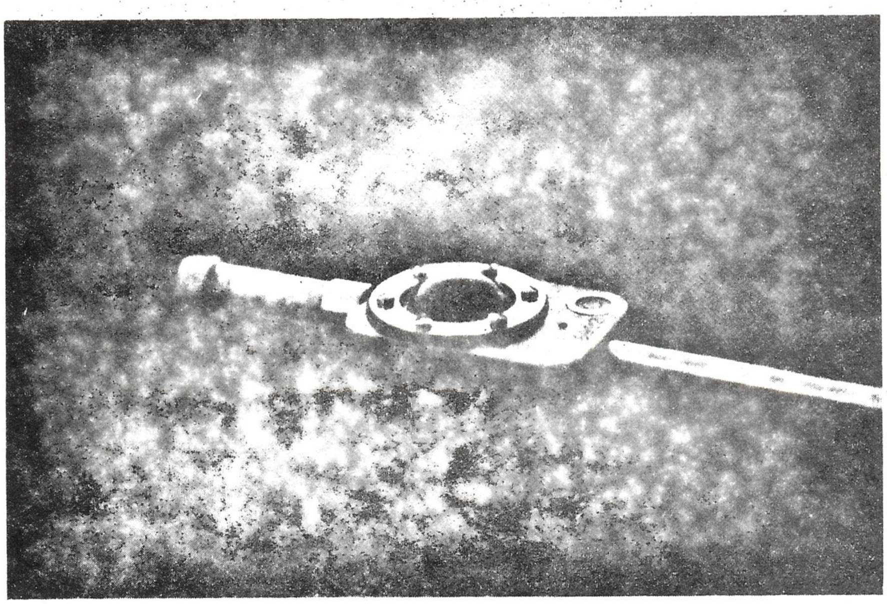


PLATE 7 NET RADIOMETER

counter-balanced vane which rotates a precious metal wiper over a wire-wound potentiometer. The wind speed and direction recorder is shown on Plate 8 with the hygrothermograph for measuring temperature and RH.

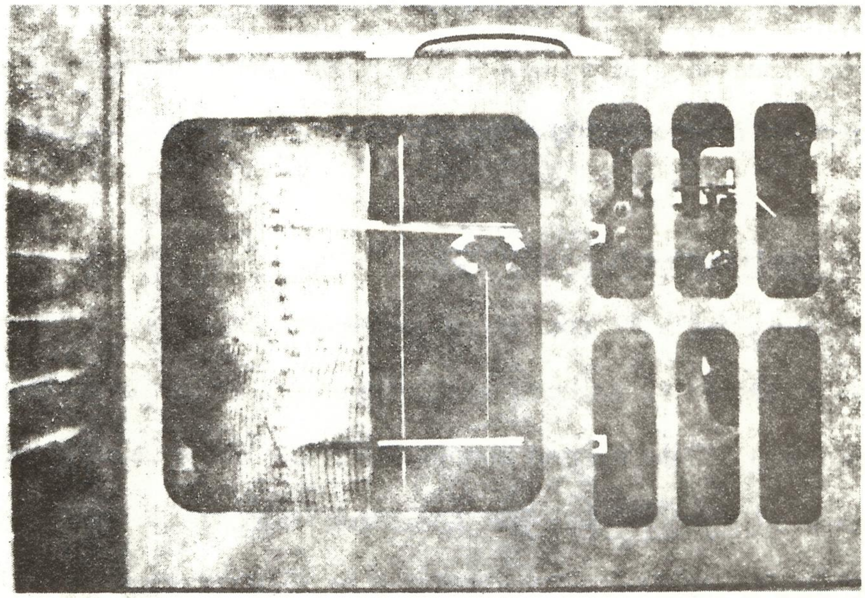
Temperature and Relative Humidity (RH)

Temperature and RH are continuously recorded on a hygrothermograph. Temperature is sensed by an aged bimetal element which distorts with changes in temperature. A specially treated bundle of human hair is used to measure RH over the full range of 0 to 100%. The linearized response of the temperature and humidity sensors is recorded on a wind-up drum type recorder. The accuracy of the temperature recording is approximately $\pm$ 1% while the humidity is accurate to $\pm$ 3% at the extremes and $\pm$ 1% at mid-scale. The hygrothermograph is shown on Plate 8.

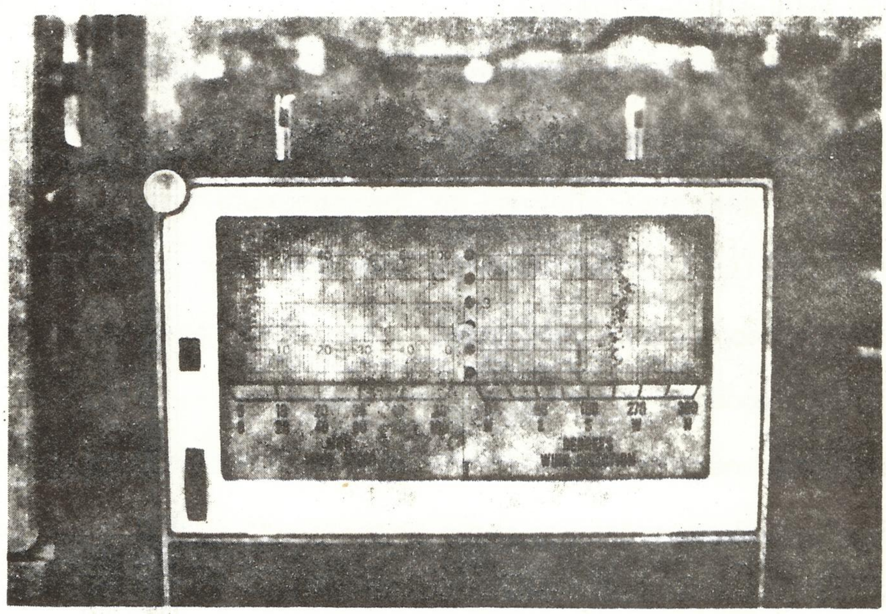
OLFACTOMETRIC MEASUREMENTS

All olfactometric (odor) measurements were completed with the EUTEK SYSTEMS Direct Reading Olfactometer (DRO). The DRO measures odor concentrations in terms of dilutions to the minimum detectable threshold odor concentration (MDTOC), or equivalently, odor units per cubic foot of air (ou/cf) under carefully controlled conditions. The DRO objectively measures the detectability of the odor.

Ambient odor measurement with the DRO is shown on Plate 9. The DRO unit consists of an enclosure containing an air pump with several air flow metering tubes, a response cord, and a mask. The mask is utilized to isolate the subject from ambient odors. The response cord is utilized for electronic communication between the subject and the DRO operator. The response cord is used to maintain subject



HYGROTHERMOGRAPH (TEMP AND RH)



WIND SPEED AND DIRECTION RECORDER

PLATE 8 WEATHER INSTRUMENTATION

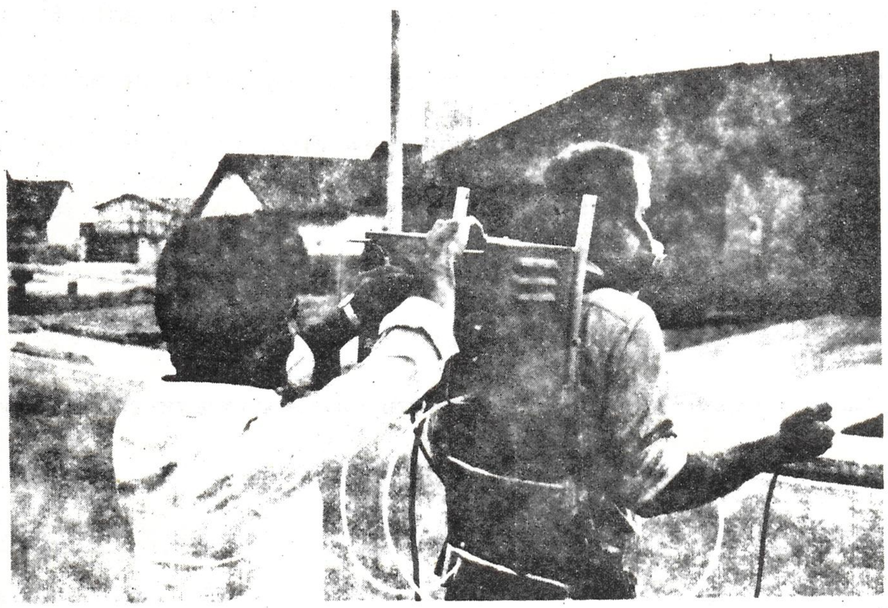


PLATE 9 AMBIENT ODOR MEASUREMENTS WITH DRO

operator objectivity. The operator provides the subject varying dilutions of odorous air with clean carbon-filtered air at timed sequences until the subject begins to detect a change in background odor. When this point is reached, the odor concentration is recorded as ou/cf, the number of dilutions to reach this threshold.

The DRO can be utilized directly in ambient air to measure odor concentrations or it can be utilized with bagged samples of odorous air. If odor concentrations are extremely high, the DRO is utilized in conjunction with a pre-dilutor to extend the range of the unit. The DRO by itself can measure odor concentrations up to 300 ou/cf. With the pre-dilutor, odor concentrations of up to 60,000 ou/cf or more can be measured.

The measurement of unit area surface odor emission rate (unit area SOER) is shown on Plate 10. A small area of an odor emitting source is isolated with a hood or bucket. Air is pumped from the hood at a constant rate. Replacement air enters the hood through a carbon filter. The odorous air pumped from the hood is then sampled through the DRO to determine its odor concentration. The unit area SOER is proportional to the odor concentration times the hood airflow rate and inversely proportional to the surface area isolated.

Study Procedures

Ambient odor measurements were made as a routine part of the BKK Landfill odor study. The primary interest of the study was to determine the distribution and concentration of odors in residential areas adjacent to the landfill. This information, in turn, was utilized to estimate overall site odor emissions. Two methods were utilized to identify areas where measurable odor concentrations existed. The first method was to drive and walk areas downwind of the landfill to determine whether measurable odor concentrations existed. If measurable odors were encountered an ambient odor measurement was made.

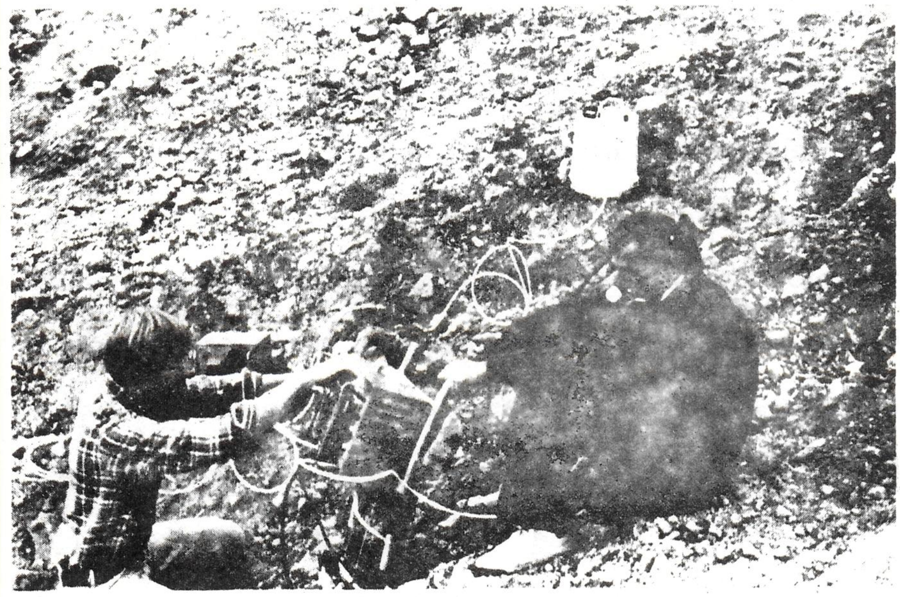


PLATE 10 SOER MEASUREMENT WITH DRO

The second method for determining where measurable ambient odors existed was the odor complaint "hot line." Residents who detected odors near their homes notified the City of West Covina Communications. West Covina Communications provided EUTEK with a portable transceiver which placed EUTEK in direct contact with Communications. Upon receipt of an odor complaint, Communications would immediately notify EUTEK of the time, location and name of the complainant. EUTEK odor monitoring crews would then utilize this information to followup with ambient odor measurements at the site of the complaint. If detectable odor concentrations were encountered upon arrival, the odor concentration was measured. If no odors were detectable, the odor monitoring crews made note of this fact and moved into other areas to locate detectable odor concentrations.

The DRO was utilized to directly measure odor concentrations from various sources within the landfill. For source odor measurements, such as the odor concentration of the landfill gas, bagged samples were utilized. The odor concentration of the air in the sample bag was then determined olfactometrically.

Unit area SOER measurements were completed during the course of the study. Selected areas of the landfill were chosen for unit area SOER measurements to document the variability and nature of the odor emissions. Unit area SOER measurements were also utilized to determine the effect of the implementation of new gas recovery wells on surface odor emissions in the vicinity of the wells.

TRACER MEASUREMENTS

Tracer studies were completed in order to determine the site dispersion characteristics and to evaluate the effectiveness of barriers and water aerosol for large area odor mitigation. Tracer measurements were completed in conjunction with ambient odor measurements to estimate the overall site odor emission rate and to determine the probable source of landfill odors.

Similar procedures were utilized for all tracer studies. A compressed gas cylinder of an inert odorless tracer, sulfur hexaflouride (SF_6), was placed within the landfill (Plate 11). Tracer was released at a controlled rate. Tracer was sampled at downwind locations utilizing a 60 cc syringe as shown on Plate 12. Tracer concentrations in the syringes were determined with a gas chromatograph (GC) specifically designed to detect SF_6. The GC is shown in Plate 13. The GC unit is sensitive to 0.01 ppb.

Dispersion Measurements

The site specific dispersion characteristics of the BKK Landfill were determined utilizing tracer measurements. Under critical micrometeorological conditions a series of cross-wind tracer sampling traverses were completed. Typically 20 to 30 or more syringe samples were taken in a 1000 to 3000 foot traverse. All samples in the cross-wind traverse were analyzed to determine which sample had the peak concentration of tracer. The peak concentration was assumed to represent the centerline concentration and was utilized to back-calculate the dispersion that occurred between the source of the tracer and the downwind location which contained the peak tracer concentration.

Probable Source of Odors

In order to determine the probable source of odors within the BKK Landfill, tracer gas concentration measurements were conducted in conjunction with

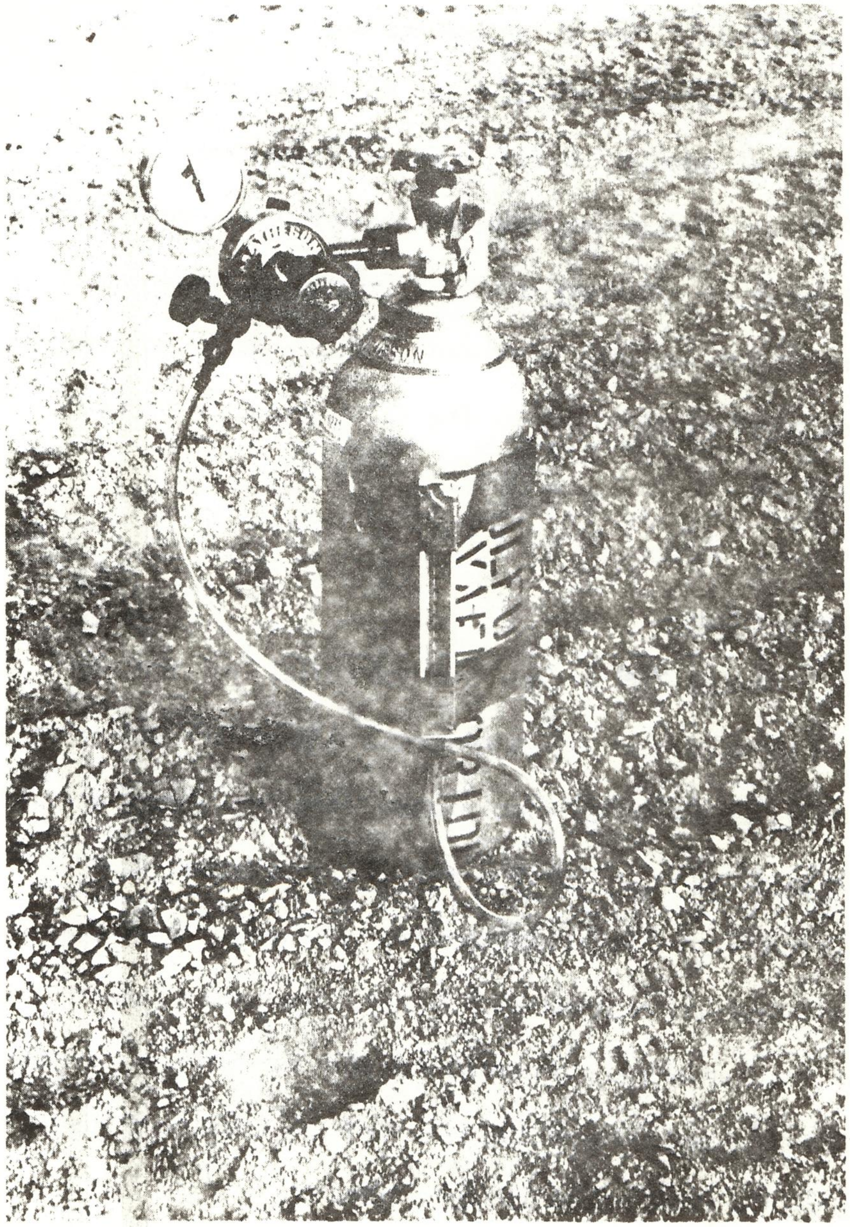


PLATE 11 SF_6 TRACER APPLICATION

PLATE 12 SF_6 TRACER SYRINGE SAMPLING

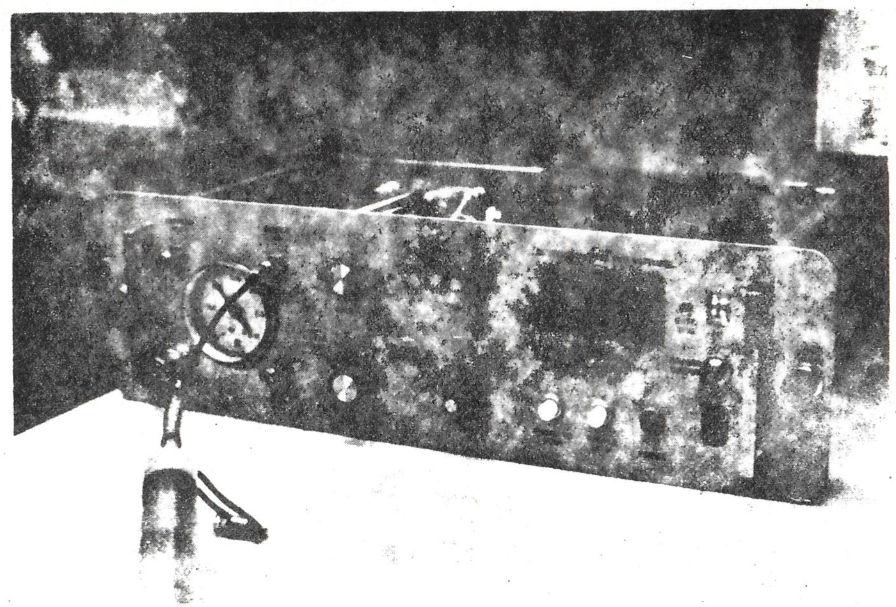


PLATE 13 SF_6 TRACER ANALYSIS WITH GAS CHROMATOGRAPH odor measurements. The SF_6 cylinder location was identified using the coordinate system as shown on Figure 2. At the time of each odor measurement, a syringe sample of ambient air was taken to determine tracer concentration. If both tracer and odor were present in measurable quantities it could be concluded that the odor came "wind-directionally" aligned with the tracer location (upwind, at, or downwind of the tracer location). If there was no tracer but measurable odor concentrations or if there was no odor but measurable tracer concentrations it could be concluded that the odor was coming from a source not wind-directionally aligned with the tracer. By moving the tracer location within the landfill site it should be possible to determine the major sources of odor.

Site Odor Emission Rate

The overall site odor emission rate was estimated utilizing paired tracer and ambient odor measurements. If the tracer was placed at the point of odor emissions, dispersion conditions would be equivalent for tracer and odor. In this case,

$$\frac{c_o}{Q_o} = \frac{c_t}{Q_t} \qquad (1)$$

Where:

c_o = odor concentration (ou/cf)

Q_o = odor emission rate (ou/min)

c_t = tracer concentration (v/v)

Q_t = tracer mass emission rate (cf/min)

The tracer mass emission rate is known as was the downwind odor and tracer concentration, thus

$$Q_o = (c_o/c_t) \quad Q_t \qquad (2)$$

In practice, the tracer was not at the odor source location because the odors were found to be emitted over multiple areas whereas the tracer was a single point source. Adjustments were made to the apparent Q_o to account for this fact.

SMOKE FLOW VISUALIZATION

Smoke candles were utilized to visually determine air flow and dispersion conditions. Five minute smoke candles were lit at various locations within the landfill to visualize air flow movements and to visualize the effects of various large emission area control systems. Photo documentation of the smoke flow visualization was difficult because the stable conditions of interest most often occur during nighttime hours. Results of the smoke flow visualization were reported qualitatively.

TEMPERATURE PROFILE MEASUREMENTS

Temperature profile measurements were completed utilizing a digital temperature indicator sensitive to 0.01 ^{o}F. Temperature for a given location was recorded as the 30 sec. average reading. The temperature probe was hand held at the required location and elevation. Temperature profile measurements are shown on Plate 14.

BARRIER EVALUATION

Sharp edge barriers were evaluated as a potential large area odor mitigation system for the BKK Landfill. A temporary barrier system was constructed across approximately 300 feet of the "West Window" of the BKK Landfill. The temporary barrier system is illustrated on Plate 15. The barrier was constructed by

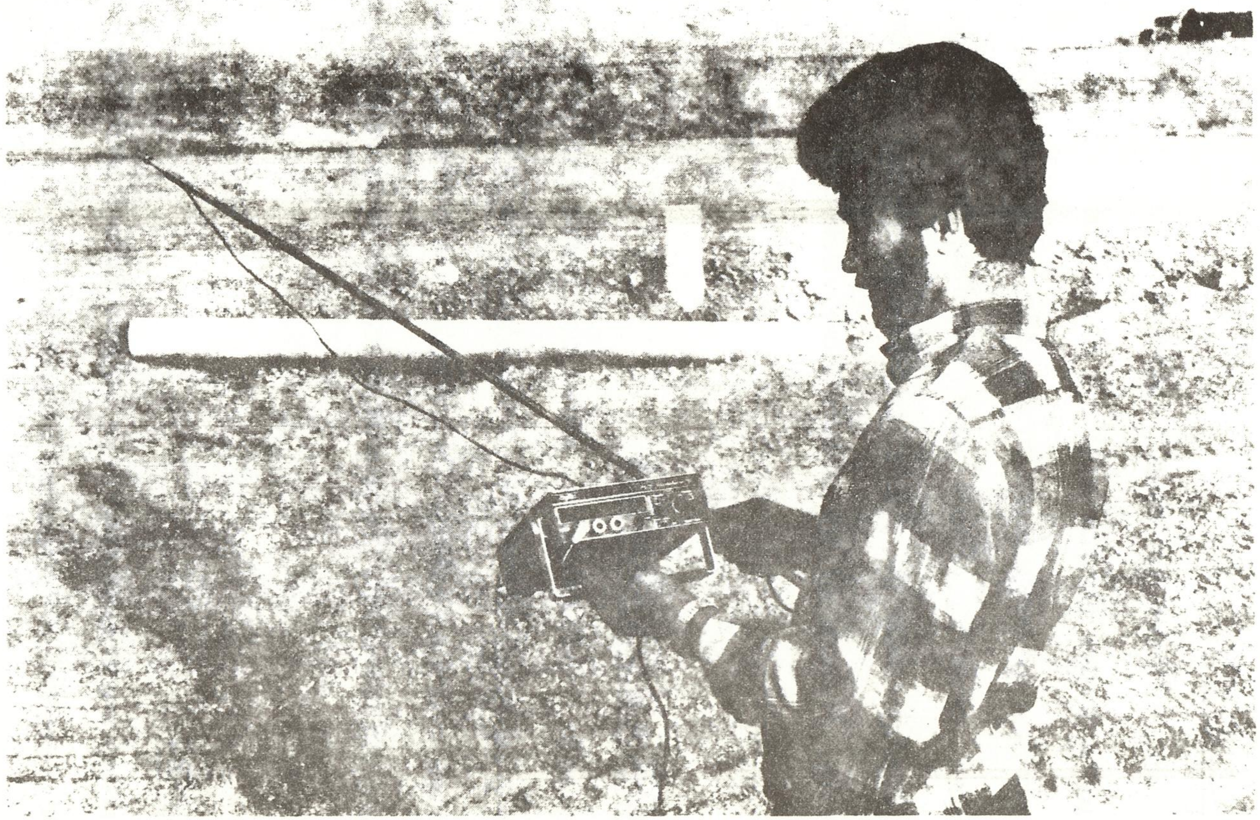


PLATE 14 TEMPERATURE PROFILE MEASUREMENTS

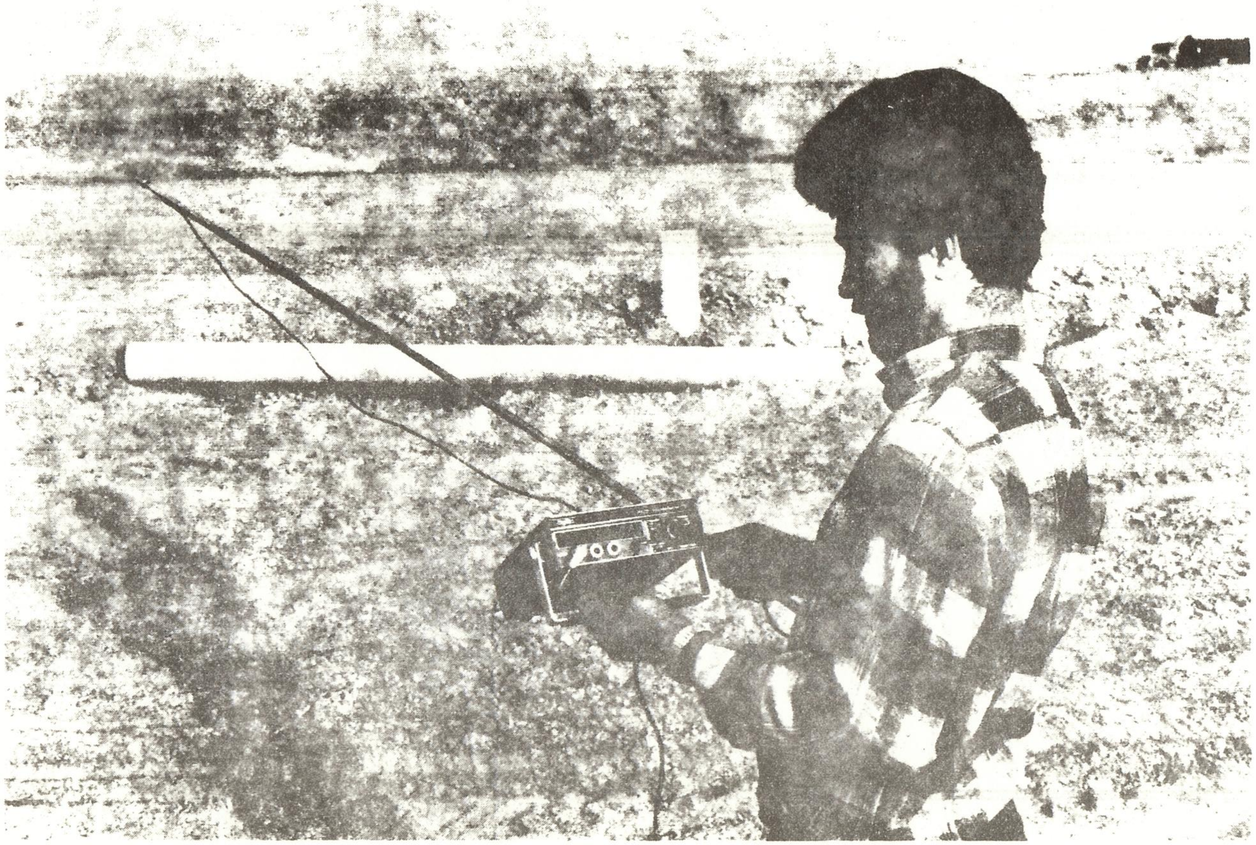


PLATE 14 TEMPERATURE PROFILE MEASUREMENTS

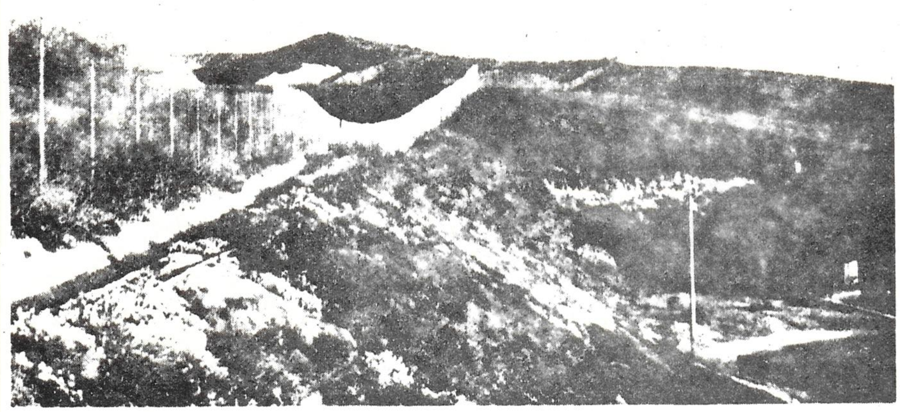


PLATE 15 WEST WINDOW BARRIER

placing and tying 3/8 inch by 4 x 8 plywood upright against an existing chain link fence. The barrier was placed across the lowest point of the "West Window" and had an effective height of 8 ft.

The effectiveness of the barrier system was evaluated uitilizing tracer, smoke visualization and temperature profile measurements. The tracer measurements were completed by placing tracer gas (SF_6) upwind of the barriers and monitoring tracer concentrations simultaneously upwind and downwind of the barrier. Baseline upwind and downwind conditions were established prior to barrier construction. Upwind barrier tracer concentrations were monitored at WS-2 while downwind concentrations were monitored at the Lynn Court turnaround (approximately 100 ft. downwind of the barrier). The objective of a sharp edged barrier system was to reduce downwind concentrations by inducing vertical mixing as wind travels over the barriers at speeds in excess of 2 mph. The barriers could be shown to be effective if downwind concentrations are consistently lower than upwind concentrations and if the trend was clearly different from pre-barrier baseline conditions.

Barrier effectiveness was also evaluated visually using smoke flow. The affect of the barriers in inducing vertical mixing was evaluated by observing smoke flow as the smoke crossed over the barriers.

Temperature profile measurements were completed near the barriers in order to evaluate the affect of the barriers on the movement of cold air within the landfill. Temperature measurements were completed by measuring temperature versus height upwind and downwind of the barrier.

WATER AEROSOL EVALUATION

A water aerosol system was constructed and evaluated to determine its potential for mitigation of odors. The system is shown on Plates 16, 17 and 18. The

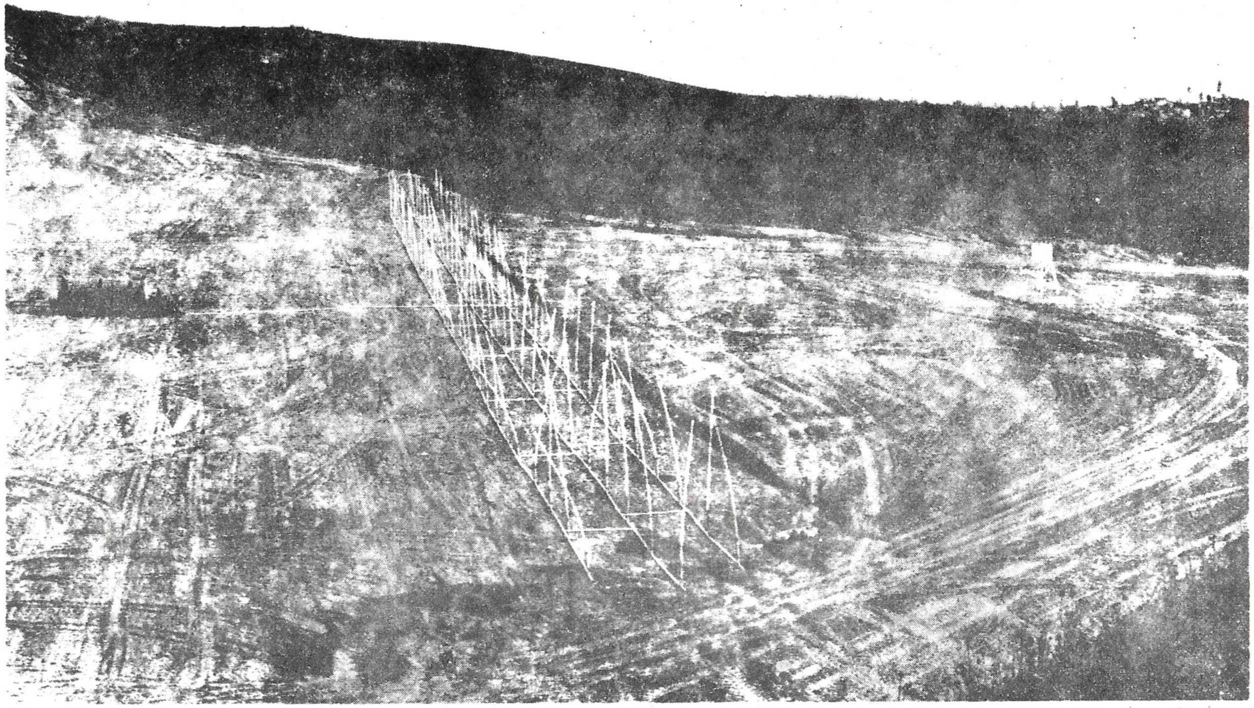


PLATE 16 WATER AEROSOL SYSTEM IN WEST WINDOW

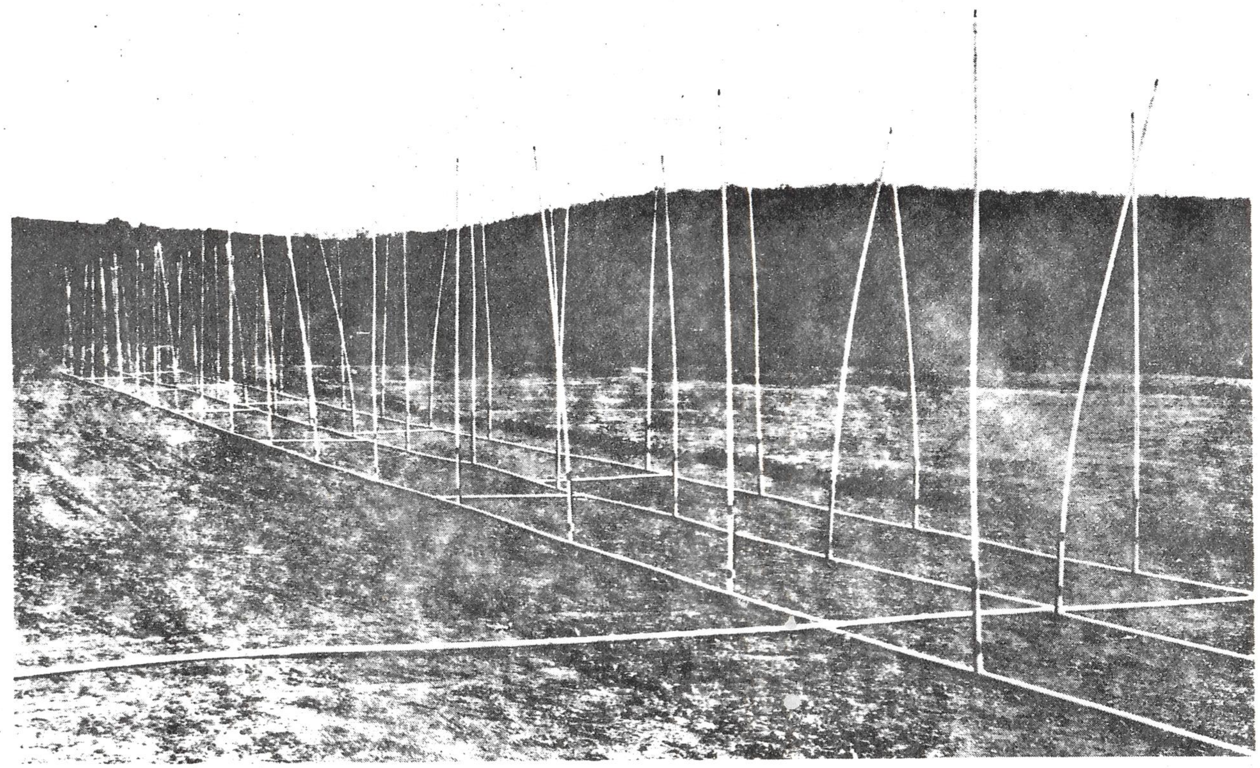


PLATE 17 WATER AEROSOL SYSTEM

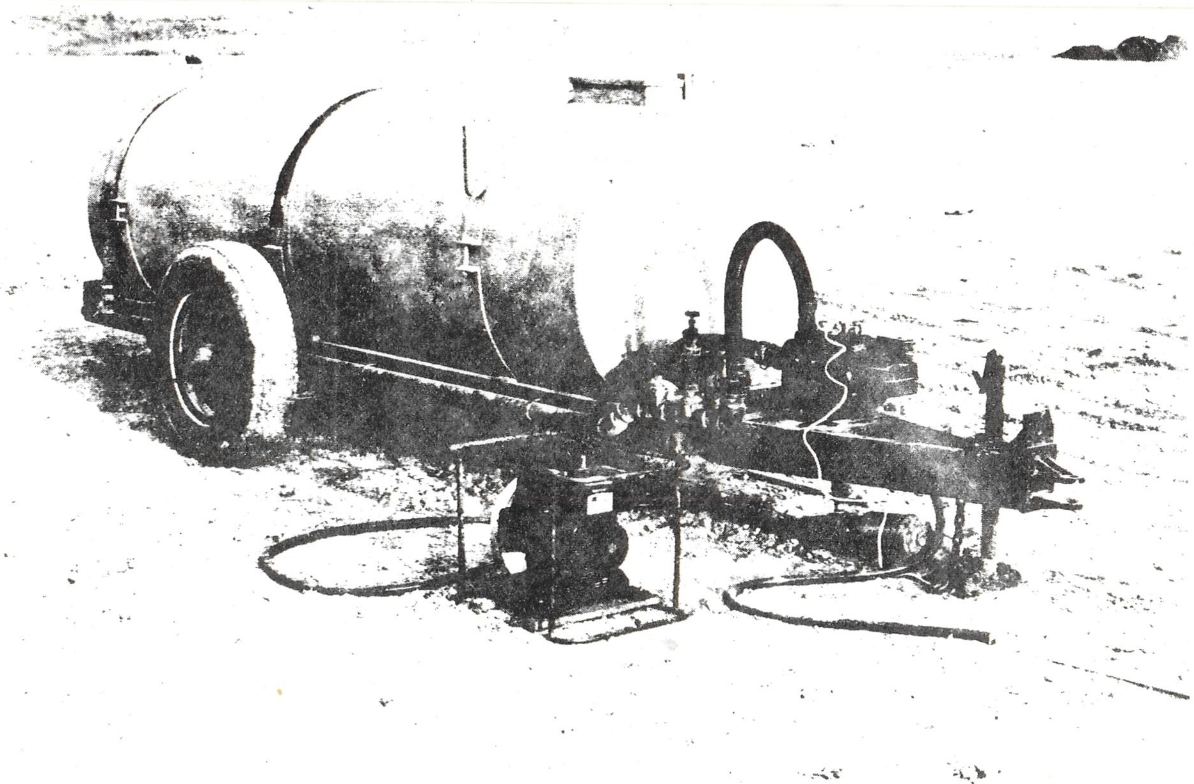


PLATE 18 WATER AEROSOL SYSTEM—STORAGE TANK, PUMP AND GENERATOR

system was constructed along approximately 330 ft. of the "West Window". The system consisted of a total of 100 nominal three gallon per hour horizontal spray atomizing nozzles, each discharging at 10 ft. above ground level. Water was supplied from a portable storage tank with a capacity of approximately 1100 gallons. The water was pumped at 71 psig to the nozzles. A schematic of the system is presented on Figure 3.

The water aerosol system was evaluated utilizing procedures similar to those used for the evaluation of the barrier system. Tracer measurements were completed by placing tracer gas (SF_6) upwind of the aerosol system and monitoring tracer concentrations simultaneously upwind and downwind of the aerosol system. If downwind tracer concentrations were significantly lower than upwind tracer concentrations, it could be surmised that the aerosol system had affected the mixing conditions.

Smoke flow visualization was also utilized in the water aerosol system evaluation.

Measurements of RH upwind and downwind of the water aerosol system were completed to determine the affect of the system on local micrometeorology. Based on the work of others, the net counter radiation occurring from the ground is a function of RH (3). As RH increases net counter radiation decreases with a concomitant reduction in temperature gradient. This, in turn, should allow a greater degree of vertical mixing to occur from sharp-edged barriers under wind conditions.

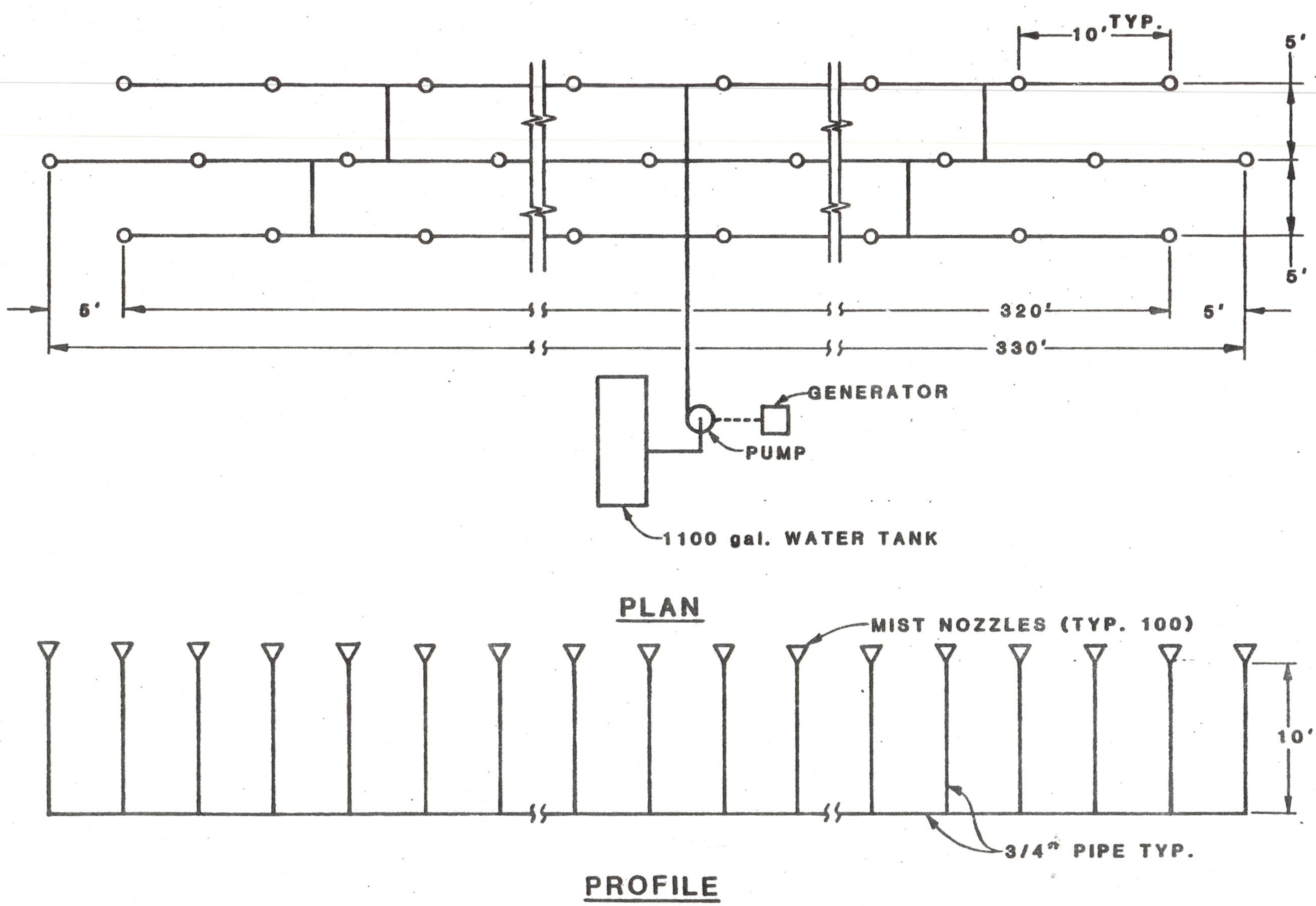


FIG. 3 WATER AEROSOL SYSTEM SCHEMATIC

V. DISCUSSION OF RESULTS

HISTORICAL ODOR COMPLAINT ANALYSIS

An analysis of odor complaints received by the City of West Covina between June 28, 1979 and November 11, 1980 has been completed. The beginning date corresponds to the end of the USC historical odor complaint analysis.(4) The ending date was the latest available complaint data at the time of the analysis. The analysis was completed to identify seasonal and diurnal trends in odor complaints. The mapping of complainant locations and relative frequency of complaints served to identify the relative sensitivity of areas surrounding the BKK Landfill to odor emissions.

The odor complaint data was obtained from Development Services Department of the City of West Covina. The complaint data included the date, time, address, name of complainant and a description of the odor. Odor complaints are also filed with the AQMD, but, no attempt was made to analyze this data as it was not as complete as the City's odor complaint data. In many cases the AQMD complaints were duplicates of the City complaints.

A total of 250 complaints were analyzed for the 1979 year and 534 for the 1980 year-to-date. A tabular summary of the complaints versus month and day of the week is presented on Table I for 1979 and 1980. With the exception of one month (July) the number of odor complaints has increased in 1980 over those in 1979.

A number of factors could be responsible for the increase in the number of odor complaints. Odor emissions from the landfill may have increased. Public awareness of odor problems at the BKK Landfill has increased dramatically. The City has advertised phone numbers to call in the event of odor complaints. Finally, organized efforts may be contributing to the increase in the number of

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TABLE 1

NUMBER OF ODOR COMPLAINTS VERSUS MONTH AND DAY

	Number of Complaints															
	June - December 1979								January - November 11, 1980							
Month	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total Per Month	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total Per Month
January									2	3	1	6	0	7	0	19
February									6	12	5	8	6	5	7	49
March									4	9	14	9	7	7	4	54
April									3	11	4	7	5	1	2	33
May									1	1	4	1	1	2	2	12
June	0	0	0	1	11	3	0	15[a]	5	3	7	12	10	4	9	50
July	19	7	7	5	12	15	10	75	4	2	3	4	3	3	4	23
August	2	3	6	12	8	2	4	37	5	6	8	7	13	7	4	50
September	3	11	4	5	17	9	9	58	28	21	7	29	12	9	15	121
October	7	2	0	12	11	4	7	43	16	27	18	5	12	15	11	104
November	1	3	0	2	3	2	2	13	3	2	3	4	3	1	3	19[a]
December	0	1	2	1	1	1	3	9								
Totals	32	27	19	38	63	36	35	250	77	97	74	93	72	61	61	534

[a] Partial months data.

complaints. Thus, it would be impossible to ascertain simply from the number of odor complaints whether odor conditions are actually better or worse in 1980 than they were in 1979.

The number of odor complaints versus month for 1979 and 1980 are presented in bar charts on Figures 4 and 5. When evaluating the 1980 year, of particular interest is the dramatic increase in the number of complaints during the months of September and October. The frequency of critical transport conditions in other locations has been observed to increase significantly in the fall months over that which occurs during the summer months. The phenomena of increased odor complaints can be explained by the onset of more stable meteorological conditions with the passing of the fall equinox. The reason for the lack of a similar increase during the fall months of 1979 is unknown.

The number of complaints versus time of day is presented in bar chart form on Figures 6 and 7. Figures 6 and 7 show that the highest frequency of odor complaints occur during the evening and early morning hours. Again, this phenomena can be explained by meteorological conditions. The onset of a nighttime radiation inversion will create critical transport conditions. Another possible explanation exists for the high frequency of odor complaints during these hours. The evening hours are the hours in which residents return home from work and this may account for the high frequency of odor complaints between 6 p.m. and midnight. During the early morning hours residents are leaving for work and this may account for some complaints. Based on previous studies it seems likely that complaints are more frequent during the evening and early morning hours because of critical micrometeorological conditions occurring during these hours.

An analysis of the number of complaints versus day of the week was completed in order to determine how landfill operations may affect the number of odor complaints.

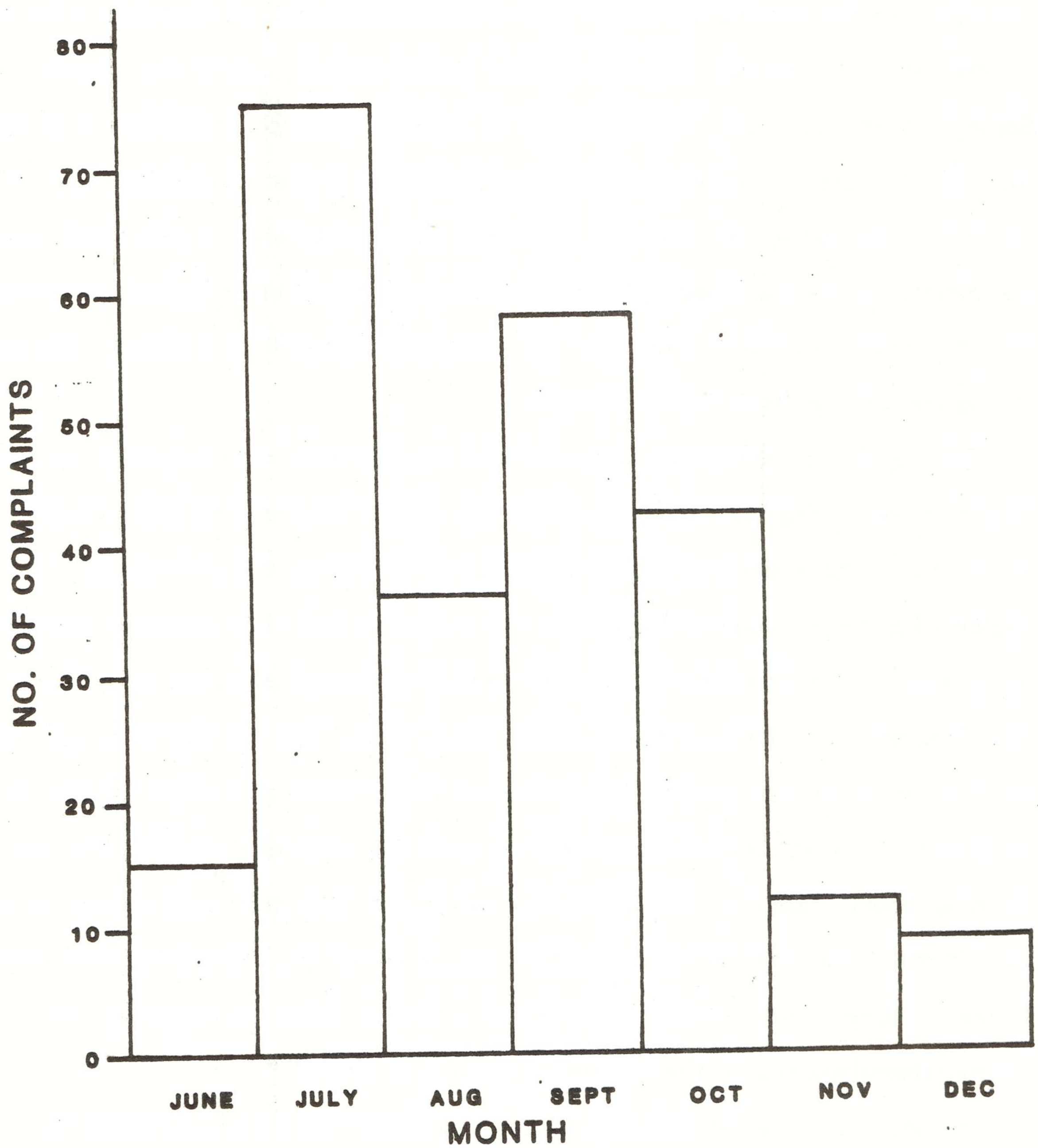

FIG. 4 NUMBER OF COMPLAINTS VERSUS MONTH, 1979

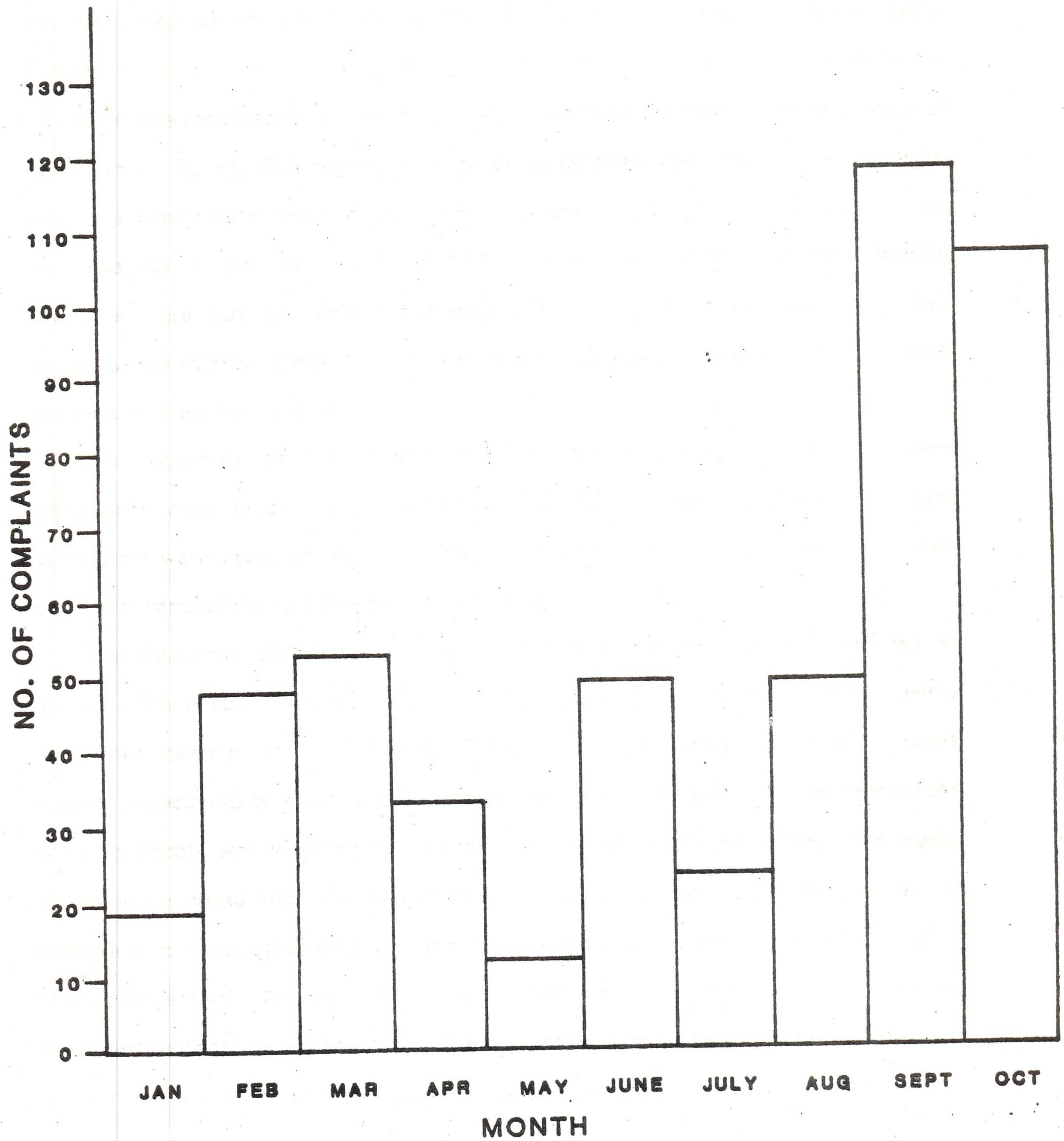

FIG. 5 NUMBER OF COMPLAINTS VERSUS MONTH, 1980

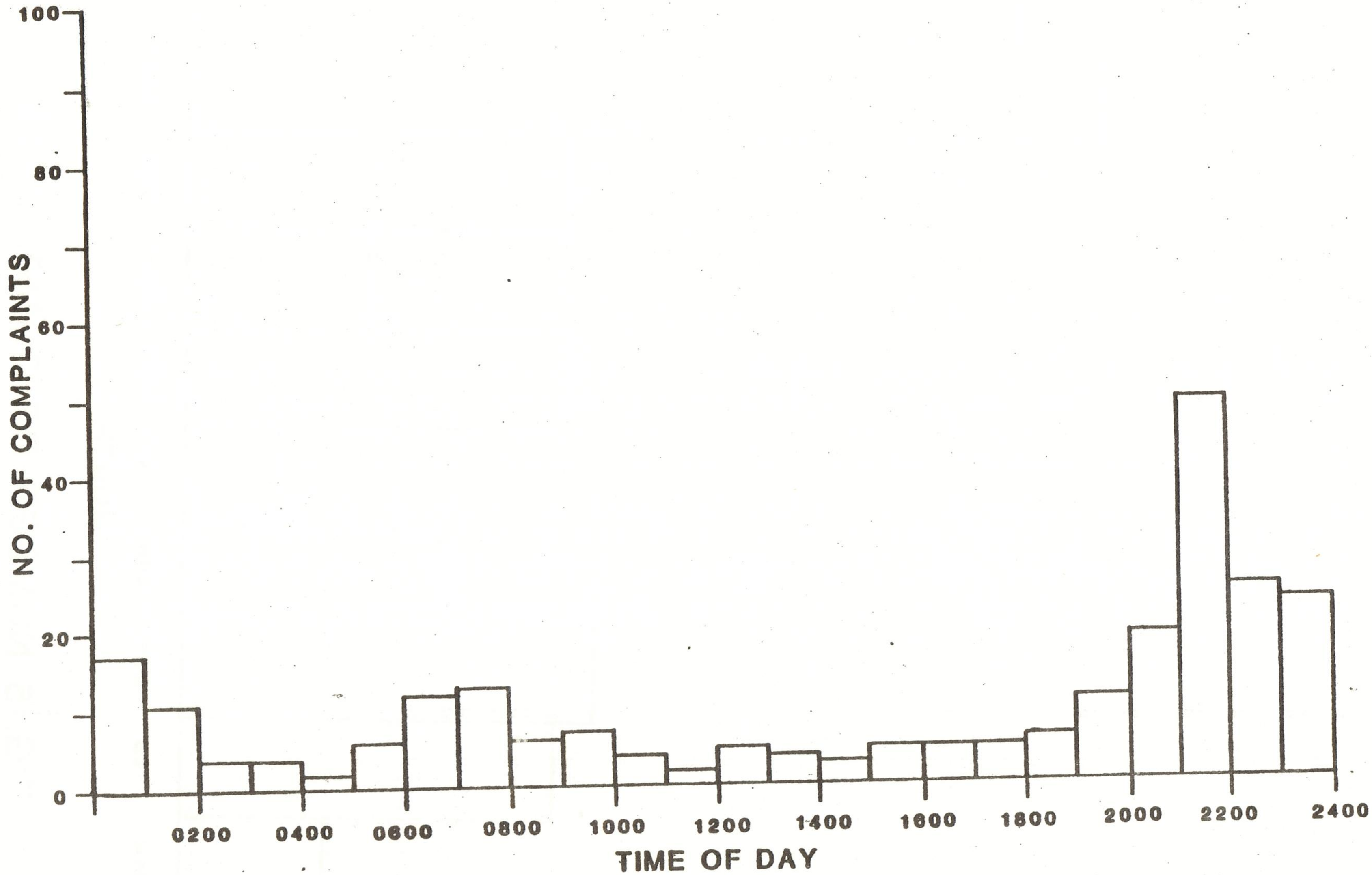

FIG. 6 NUMBER OF COMPLAINTS VERSUS TIME OF DAY, 1979

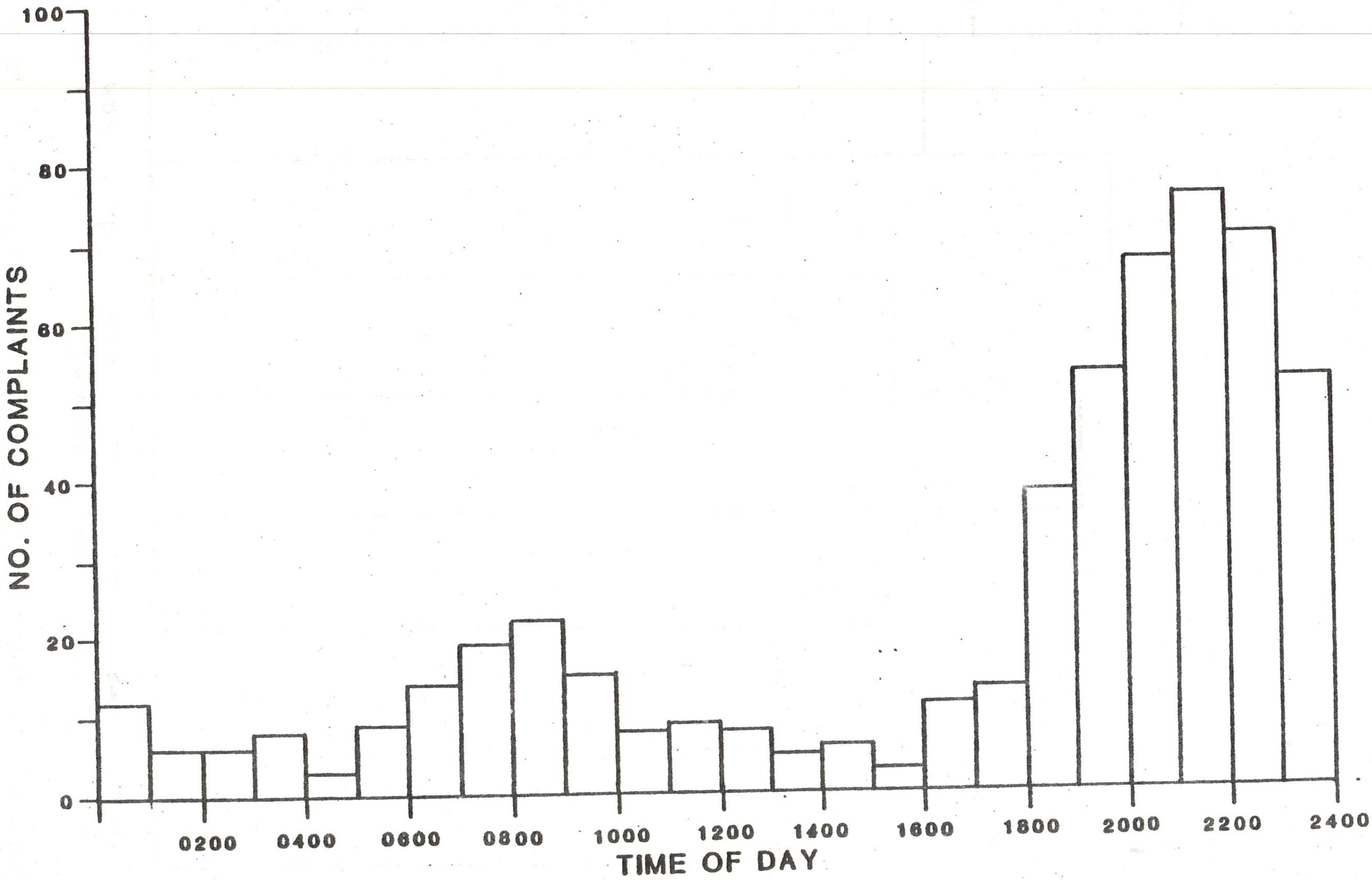

FIG. 7 NUMBER OF COMPLAINTS VERSUS TIME OF DAY, 1980

The BKK Landfill is open from 6 a.m. to 5 p.m. Monday through Saturday. Sunday is the only day in which there is no working face in the landfill. Figures 8 and 9 show the frequency of complaints versus day of week for 1979 and 1980, respectively. During 1979 the largest number of complaints were received on Friday while the minimum was received on Wednesday. Sunday received the fourth largest number of complaints. During 1980 highest number of complaints were recorded on Tuesday with the minimum number of complaints recorded on Saturday and Sunday. From this analysis it can be concluded that working face odors and daily landfill operations are not completely responsible for odor complaints received. This suggests that migrating gas and other residual odors may be contributing to the odor problem at the BKK Landfill.

The frequency of odor complaints (i.e., the percentage of days in which complaints were logged) is presented on Table 2. In both 1979 and 1980 odor complaints were received on 66 to 67% of the days. That is, on two of every three days odor complaints could be expected to be filed.

The frequency distribution of described odor characteristics are presented on Table 3. The descriptions "garbage", "chemical", and "gas" were the most frequently mentioned description of the odor. Other descriptions included "rotten", "burnt rubber", "decaying animal", and "deodorant spray". The description of "deodorant spray" probably was referring to an odor masking agent utilized in the water truck. It should be noted that the deodorant spray results in odor complaints when its purpose is to mask other odors. It should be noted that the description of an odor is highly subjective. An odor described as "chemical" by one individual may be described as "gas" by his neighbor. The only conclusion to be drawn by this analysis is that the majority of descriptions provided are not inconsistent with landfill operations.

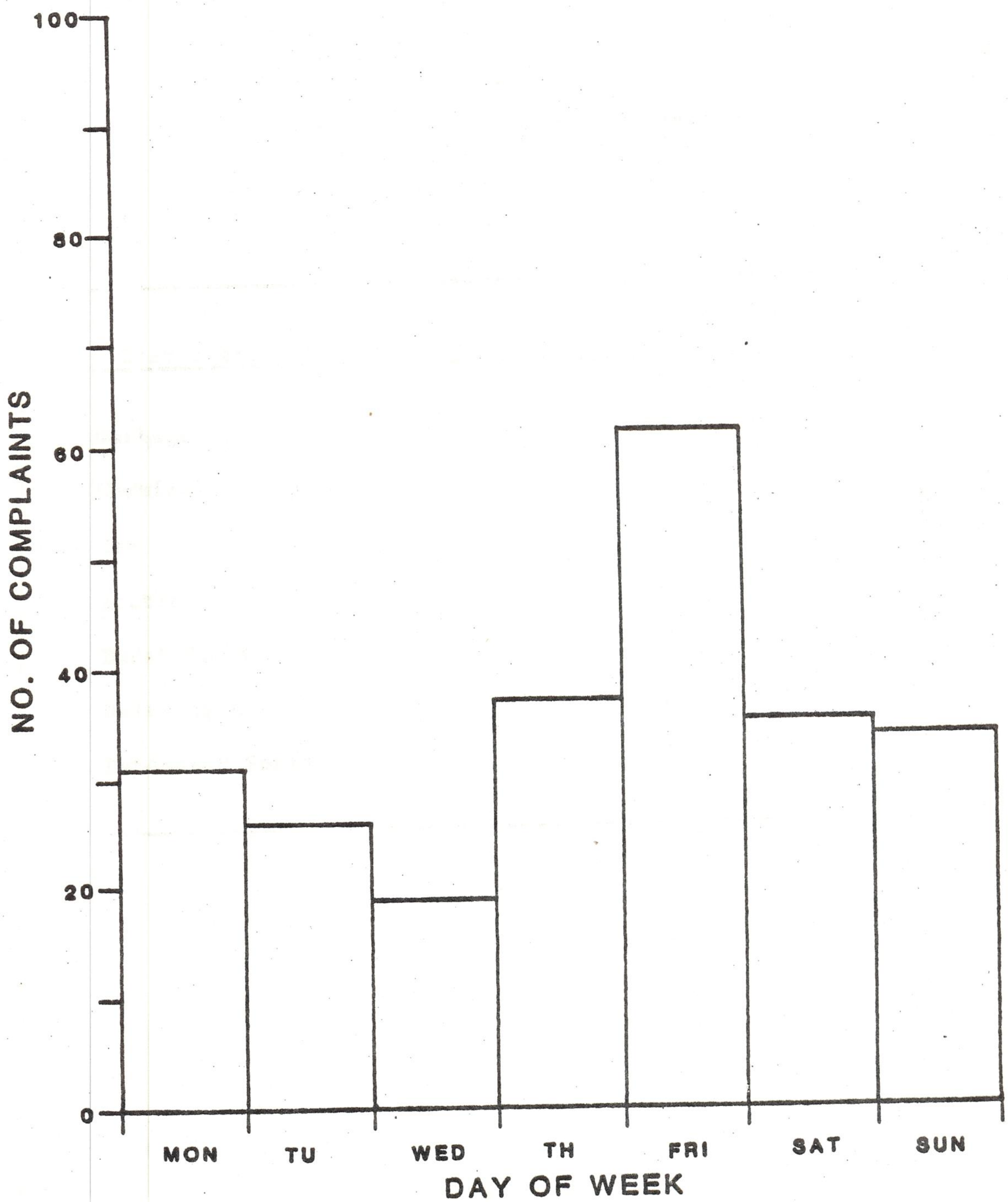

FIG. 8 NUMBER OF COMPLAINTS VERSUS DAY OF WEEK, 1979

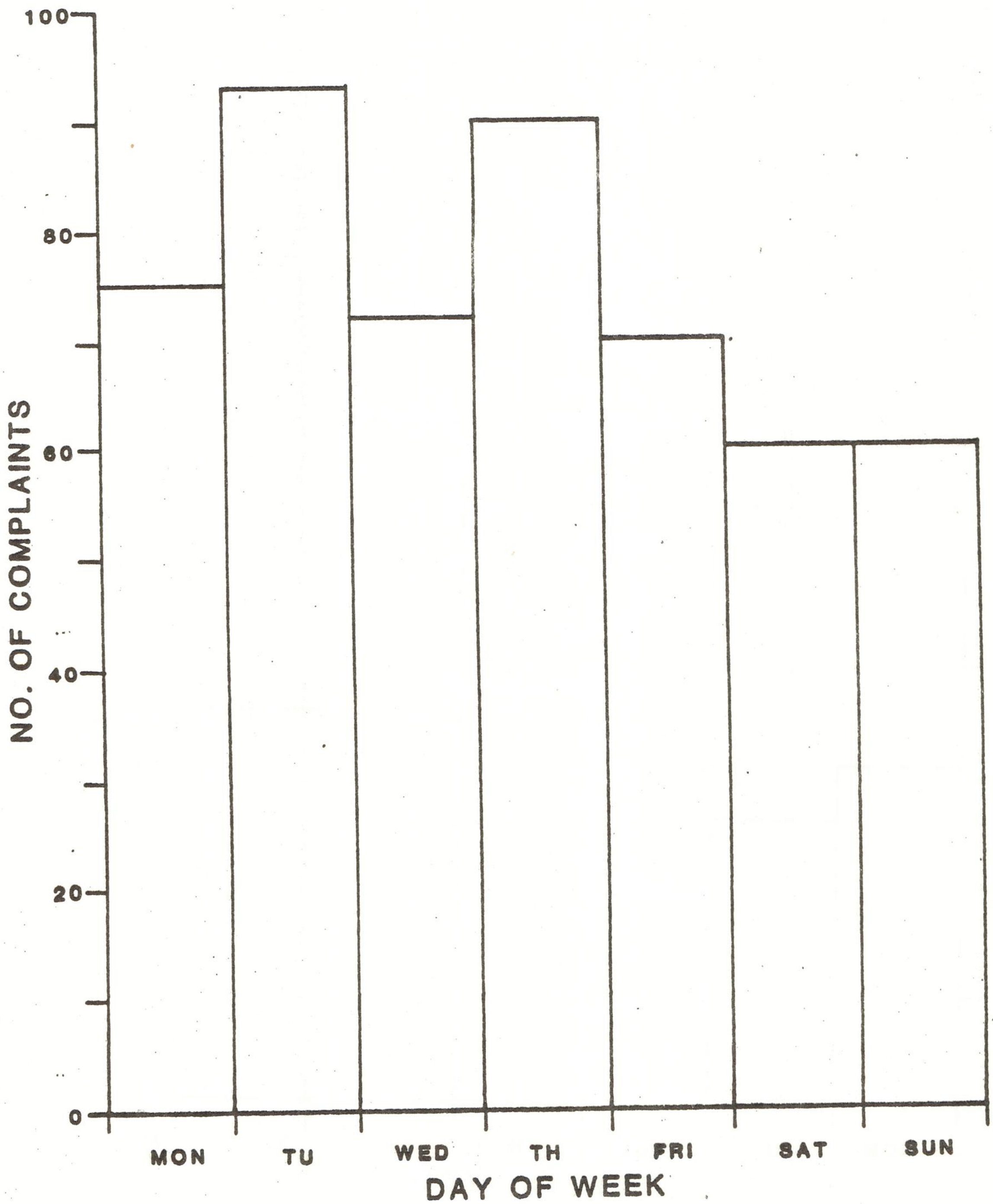

FIG. 9 NUMBER OF COMPLAINTS VERSUS DAY OF WEEK, 1980

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TABLE 2

FREQUENCY OF ODOR COMPLAINTS

(% of Days)

Month	Year 1979	Year 1980
January	—	29
February	—	59
March	—	68
April	—	53
May	—	71
June	—	87
July	87	55
August	71	81
September	83	77
October	74	87
November	37	73
December	42	
Total	66	67

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TABLE 3

DISTRIBUTION OF ODOR CHARACTERISTICS

(%)

Characteristic	Year 1979	Year 1980
Garbage	28	24
Chemical	29	39
Gas	16	16
Rotten	12	11
Burnt Rubber	6	2
Decaying Animal	7	2
Deodorant Spray	1	5

In order to determine the areas most seriously affected by the odors from the BKK Landfill, the distribution of complaints versus street name were tabulated on Table 4. A map of the area surrounding BKK Landfill is presented on Figure 10 for reference. The greatest number of complaints were logged from Miranda and Loraine Streets. Miranda Street is the closest residential area to the active portions of the landfill. In terms of groupings, the "M" and "L" Streets were the most frequent locations for complaints. The condominium development south of Amar and the area to the north of the landfill were other affected areas.

Conclusions

The following conclusions were made from the odor complaint analysis:

1. Micrometeorology apparently plays a significant role in the number of odor complaints from the BKK Landfill. This conclusion is based on the time and seasonal distribution of complaints. Odor complaints occurred most frequently during nighttime and seasons when sublayer inversions are common.
2. The most seriously affected areas are the "M" and "L" Street areas. These areas are also in closest proximity to the landfill site and will receive downslope drainage of cold air moving across the landfill. The frequency of complaints in other areas is very low relative to the L and M streets.
3. The regular occurrence of odor complaints on Sunday when there is no working face suggests odor sources other than the working face are responsible for some complaints.

SITE MICROMETEOROLOGY

The site specific micrometeorology will determine the direction in which the odors are transported and will determine the amount of dispersion that will occur

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TABLE 4

DISTRIBUTION OF COMPLAINT LOCATION

(%)

Characteristic	Year 1979	Year 1980
Miranda Street	21	25
Loraine Street	20	16
Melissa Street	11	6
Lynn Court	1	5
Paseo Olivas	3	5
Maria Court	2	4
Nanette Avenue	1	3
Aroma Drive	1	3
Hollencrest	2	2
Kings Crest Drive	2	2
Marlena Street	2	1
E. Harrington Way	0	1
Donna Beth Avénue	1	1
Elena Avenue	1	1
Rimgrove Drive	2	1
Paseo Tepic	1	1
Amar Road	5	1
Woodridge Circle	0	1
Temple Avenue	0	1
Barham Avenue	3	1

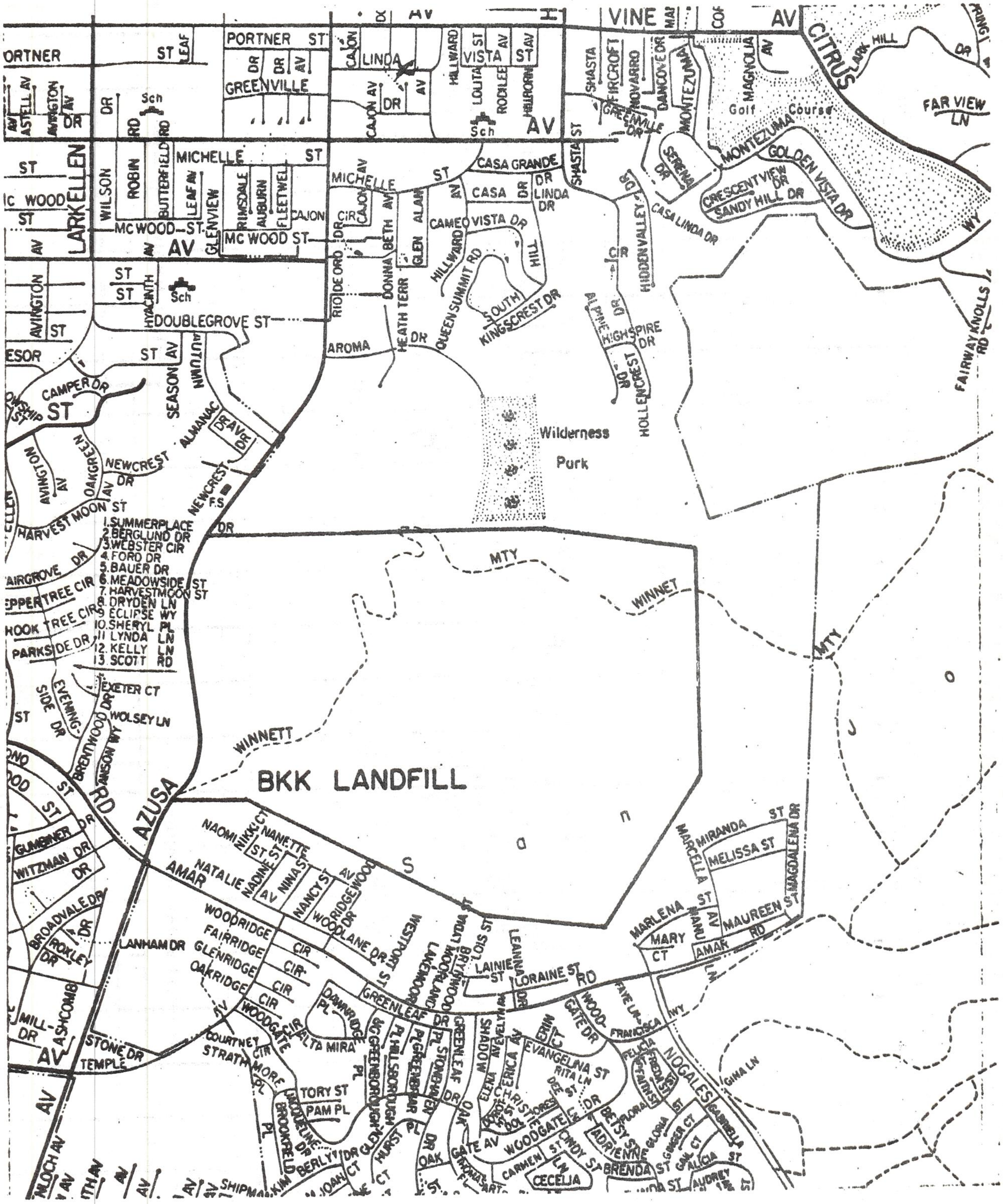

FIG.10 BKK LANDFILL AND SURROUNDING AREA

between the odor source and the downwind neighborhoods. Micrometeorological parameters considered potentially significant to odor transport which were monitored at the BKK Landfill site included wind speed, wind direction, ΔT, net radiation, temperature and relative humidity (RH). These parameters are not independent. They are influenced by large scale meteorology and by site topography. It is the unique combination of these parameters that results in the distribution and concentration of downwind odorants.

In general, worst case conditions for maximum downwind odor concentration would occur under the following conditions:

1. Strong sublayer inversion (positive ΔT)
2. Low wind speeds
3. Uni-directional wind
4. Low RH
5. Strong net counter radiation
6. Warm temperature

The micrometeorological measurements at the landfill site were designed to determine the frequency and extent to which those conditions occur. Site micrometeorological measurements were also designed to be descriptive in terms of the type of air movements that occur within the landfill area.

Of perhaps the greatest significance to downwind residents is the frequency of wind direction (i.e., the direction from which the wind blows) during times when the other parameters are critical. Odor exposure can only occur if there is wind movement aligned between the source of odors and the complainant.

Typical Diurnal Micrometeorology

A typical diurnal trace (January 19, 1981) of the six micrometeorological parameters monitored is shown on Figure 11. The following patterns noted in Figure 11 were generally typical of the months of December 1980 and January 1981:

1. Wind speed was measurable during daylight hours but during night hours frequent calm conditions of varying durations occurred. The calm conditions would begin near sunset. Often wind speed picked up again near midnight.

2. Wind direction was highly variable. No consistent diurnal wind direction pattern was observed. Wind direction was most frequently from the east. During calm conditions it was not possible to determine the true wind direction with the instrumentation.

3. ΔT showed a distinct diurnal pattern. ΔT was neutral or negative during daylight hours. At or near sunset ΔT would remain neutral to positive until sunrise. ΔT did not remain steady but was variable. The greatest variations occurred during calm wind conditions.

4. Net radiation varied directly with the overhead angle of the sun during daylight hours. If any cloud cover occurred net radiation would drop immediately to a near zero value. The net radiation during evening hours was steady and slightly negative.

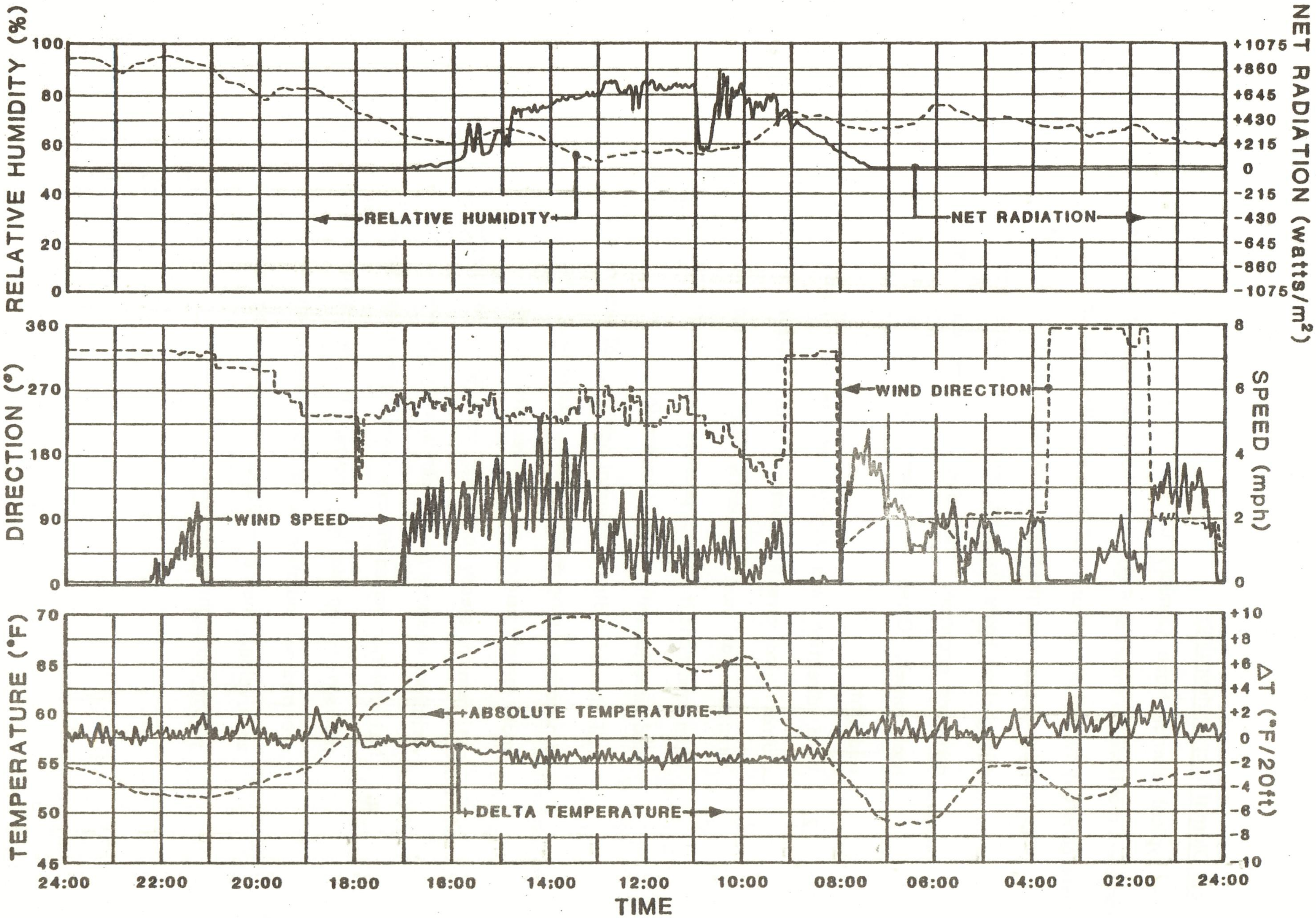

FIG. 11 TYPICAL DIURNAL WEATHER PATTERN

5. Temperature varied diurnally with the high temperature occuring mid-afternoon. The minimum temperatures occurred just prior to sunrise.

6. RH varied diurnally opposite that of temperature. The maximum RH occurred at the point of minimum temperature. The minimum RH occurred typically at the point of highest temperature.

A great majority of odor complaints that have occurred in the neighborhood surrounding the BKK Landfill have occurred during calm wind conditions with a positive ΔT indicating an atmospheric sublayer temperature inversion. It is the calm condition with a positive temperature gradient that allows for the downslope drainage of relatively cold air. The time distribution of calms with positive ΔT is strongly correlated with the time distribution of odor complaints (Figures 6 and 7).

Meteorological measurements in conjunction with smoke flow visualization and tracer studies have confirmed the observations made in previous reports that strong ground level inversions and the consequent downslope drainage of cold air will result in the transport of measurable odor concentrations to the downwind neighborhoods. Micrometeorological conditions were observed to be extremely stable during the evening and early morning hours. During most evenings wind speeds dropped below the measurable threshold of the 3-cup anemometer. The wind direction vane was deadstill at these times. When these conditions occurred, the only way to determine wind movement patterns is through the use of a smoke candle.

In the sections following each micrometeorological parameter will be discussed, a typical trace will be presented and comparisons will be made between the frequency distribution in December 1980 and January 1981.

Wind Speed And Direction

A typical wind speed and direction recording is presented in Figure 12. The wind speed and direction was measurable during daylight hours but was frequently calm during the evening hours. A calm condition is defined as any wind speed below the threshold of the 3-cup anemometer. A calm shows up as a straight line trace on the strip chart recorder on both wind speed and direction. Hourly wind speed frequency distributions for WS-2 and WS-3 for December 1980 and January 1981 are presented in Tables 5, 6, 7 and 8 respectively. Comparing WS-2 to WS-3, a higher frequency of calms occurred at WS-2 for both December and January (approximately 26% for WS-2 vs 18% for WS-3). There was not a significant difference in the frequency distribution of wind speed on a daily average basis between December and January, for either WS-2 or WS-3.

Tables 5-8 clearly show that the highest frequency of calm conditions occur between 16:00 to 23:00. The frequency and duration of calms for the BKK Landfill site is presented on Table 9. Most calms occur for a duration of one hour or less. Calms account for 18-26% of time at the BKK Landfill, an unusually high frequency. Calms occurred on greater than 90 percent of the days in both December and January. Calm frequency was approximately the same for both WS-2 and WS-3 in December and January.

The frequency of wind direction is presented as an overall site wind rose on Figures 13 and 14 for December 1980 and January 1981 respectively. The most frequent wind directions were east and northeast. Wind direction was variable throughout the day. Although the wind direction frequency changed somewhat from

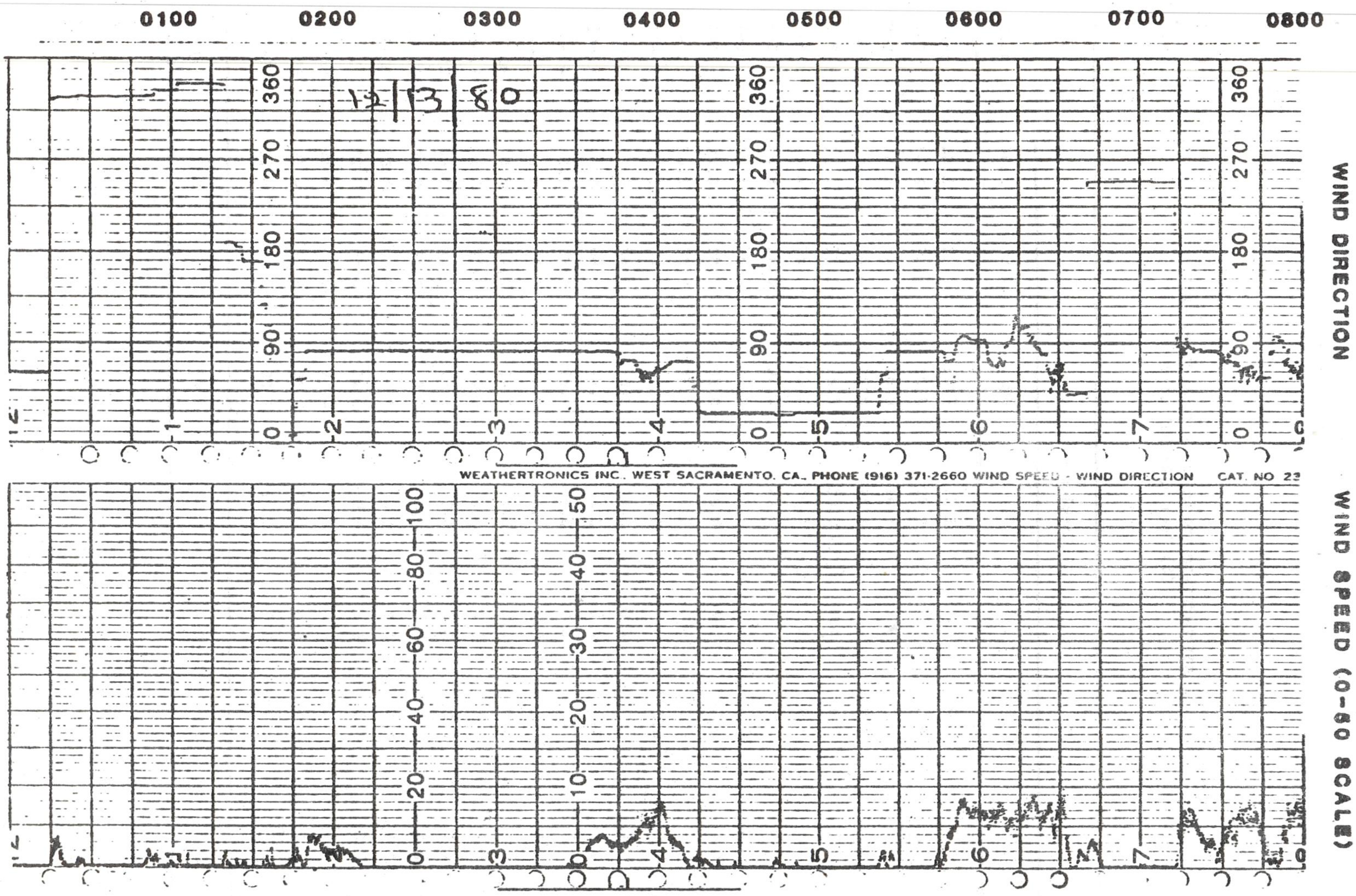

FIG. 12 TYPICAL WIND SPEED AND DIRECTION CHART
WEATHER STATION NO. 2

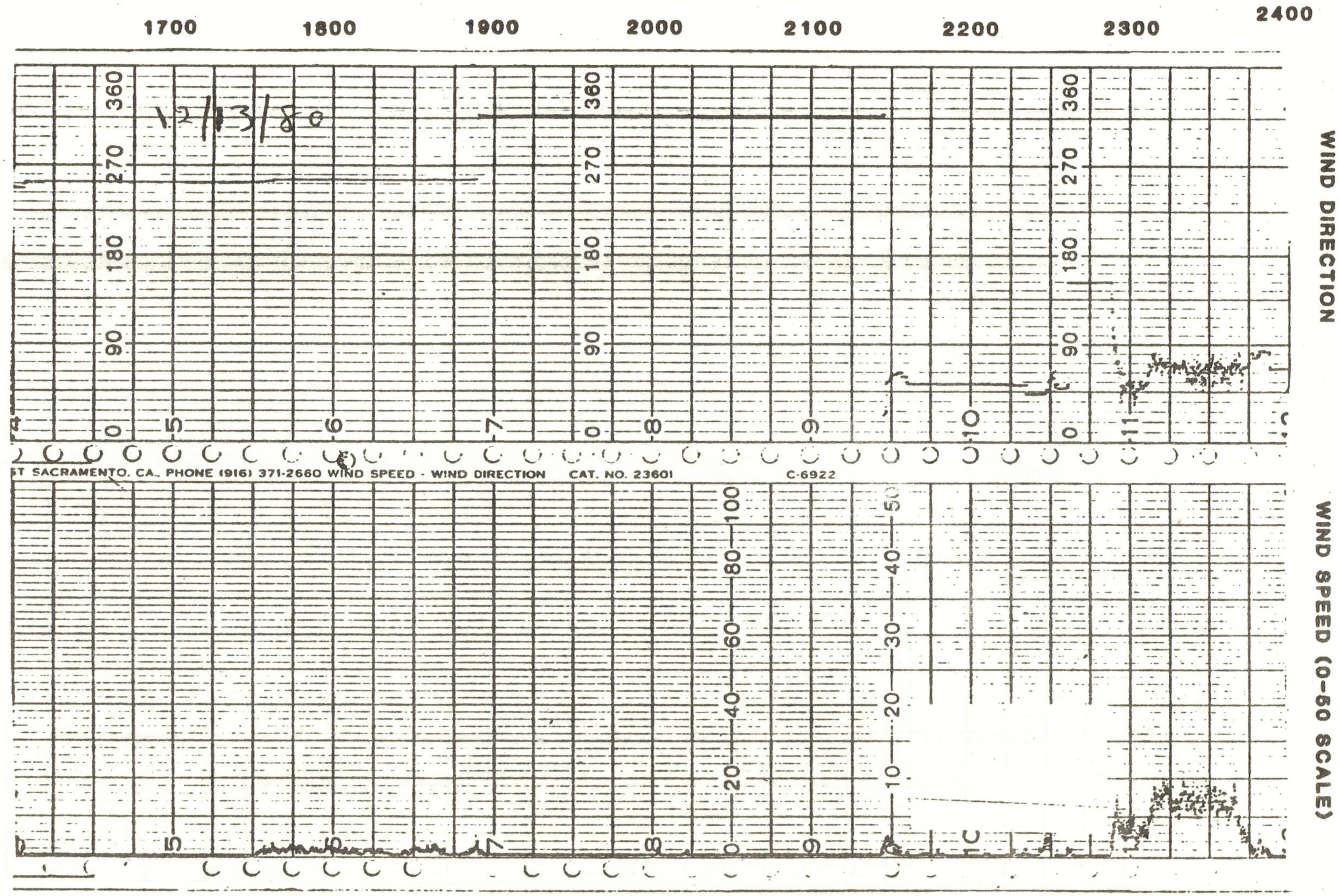

FIG. 12 (CONTINUED)

WIND DIRECTION WIND SPEED (0-50 SCALE)

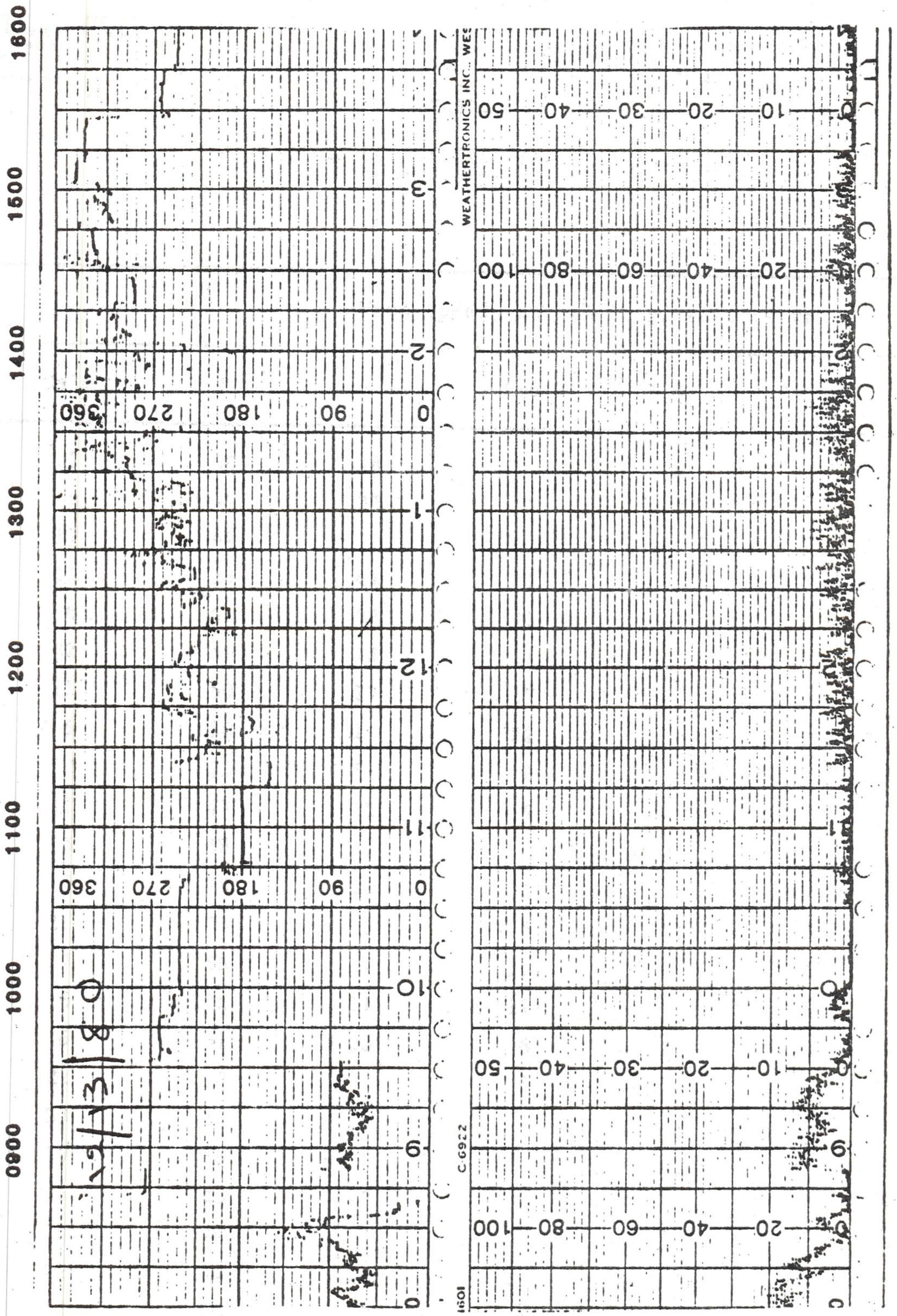

FIG. 12 (CONTINUED)

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TABLE 5

WIND SPEED HOURLY FREQUENCY DISTRIBUTION
WS-3, DECEMBER 1980 (%)

	Wind Speed (mph)						
Time	Calm	0-2	2-4	4-6	6-8	8-10	<10
24-1	22.2	33.3	18.5	22.2	3.7	0.0	0.0
1-2	14.8	44.4	14.8	22.2	3.7	0.0	0.0
2-3	18.5	37.0	26.0	14.8	3.7	0.0	0.0
3-4	11.1	29.6	37.0	18.5	3.7	0.0	0.0
4-5	11.1	33.3	18.5	30.0	7.4	0.0	0.0
5-6	7.4	25.9	40.7	14.8	11.1	0.0	0.0
6-7	14.8	14.8	37.0	29.6	3.7	0.0	0.0
7-8	11.1	29.6	25.9	29.6	3.7	0.0	0.0
8-9	16.0	28.0	32.0	20.0	3.7	0.0	0.0
9-10	20.0	32.0	36.0	12.0	0.0	0.0	0.0
10-11	16.0	60.0	12.0	12.0	0.0	0.0	0.0
11-12	8.0	56.0	28.0	12.0	0.0	0.0	0.0
12-13	4.0	68.0	24.0	8.0	0.0	0.0	0.0
13-14	8.0	56.0	28.0	8.0	0.0	0.0	0.0
14-15	8.0	56.0	32.0	4.0	0.0	0.0	0.0
15-16	8.0	64.0	24.0	4.0	0.0	0.0	0.0
16-17	56.0	28.0	12.0	4.0	0.0	0.0	0.0
17-18	34.6	42.3	23.1	0.0	0.0	0.0	0.0
18-19	30.7	61.6	7.7	0.0	0.0	0.0	0.0
19-20	35.7	43.6	10.7	0.0	0.0	0.0	0.0
20-21	32.1	46.4	14.3	3.6	3.6	0.0	0.0
21-22	21.4	46.4	21.4	7.2	0.0	3.6	0.0
22-23	21.4	28.6	35.7	14.3	0.0	0.0	0.0
23-24	21.4	32.1	32.1	14.3	0.0	0.0	0.0
Avg.	18.8	41.5	24.6	12.7	2.0	.15	0.0

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TABLE 6

WIND SPEED HOURLY FREQUENCY DISTRIBUTION
WS-2, DECEMBER 1980 (%)

	Wind Speed (mph)						
Time	Calm	0-2	2-4	4-6	6-8	8-10	10
24-1	37.1	29.6	22.2	0.0	3.6	3.6	3.6
1-2	22.2	44.4	14.8	7.4	7.4	3.7	0.0
2-3	29.6	37.1	14.8	11.1	0.0	3.7	3.7
3-4	29.6	29.6	29.6	3.7	3.7	3.7	0.0
4-5	29.6	29.6	22.2	11.1	0.0	3.7	3.7
5-6	25.9	37.1	25.9	3.7	0.0	7.4	0.0
6-7	18.5	44.4	14.8	14.8	0.0	3.7	3.7
7-8	22.2	29.6	25.9	14.8	0.0	3.7	3.7
8-9	33.3	22.2	22.2	7.4	11.1	3.7	0.0
9-10	14.8	37.1	29.6	3.7	14.8	0.0	0.0
10-11	11.1	48.2	25.9	11.1	3.7	0.0	0.0
11-12	0.0	48.2	44.4	7.4	0.0	0.0	0.0
12-13	3.7	40.7	48.2	7.4	0.0	0.0	0.0
13-14	3.7	37.1	55.6	3.7	0.0	0.0	0.0
14-15	0.0	66.7	29.6	3.7	0.0	0.0	0.0
15-16	7.4	70.4	14.8	7.4	0.0	0.0	0.0
16-17	69.2	25.9	3.8	3.8	0.0	0.0	0.0
17-18	59.3	25.9	14.8	0.0	0.0	0.0	0.0
18-19	35.7	46.4	14.3	3.6	0.0	0.0	0.0
19-20	42.9	39.3	10.7	7.1	0.0	0.0	0.0
20-21	42.9	39.3	7.1	7.1	3.6	0.0	0.0
21-22	42.9	35.7	7.1	7.1	7.1	0.0	0.0
22-23	21.4	39.3	25.0	7.1	7.1	0.0	0.0
23-24	25.0	32.1	17.9	10.7	7.1	7.1	0.0
Avg.	26	39	22	7	3	2	1

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TABLE 7

WIND SPEED HOURLY FREQUENCY DISTRIBUTION
WS-3, JANUARY 1981

	Wind Speed, mph (% in given interval)						
Time	Calm	2	2-4	4-6	6-8	8-10	10
0-1	17	50	28		6		
1-2	6	44	33	17			
2-3	17	44	39				
3-4	11	33	44	11			
4-5	6	61	22	11			
5-6	22	39	22	11			
6-7	11	50	17	17			6
7-8	6	50	17	22		6	
8-9	17	22	50	6		6	
9-10	11	47	32	5		5	
10-11	5	58	32		5		
11-12	5	79	11	5			
12-13	11	74	11	5			
13-14	17	56	17	11			
14-15	6	72	11	11			
15-16	6	61	28	6			
16-17	22	50	22	6			
17-18	33	50	17				
18-19	39	56	6				
19-20	56	28	17				
20-21	39	44	17				
21-22	22	44	22	11			
22-23	17	28	44	6		6	
23-24	17	28	44	6	6		
Avg.	17.5	48.7	25.1	7.0	0.7	1.0	0.3

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TABLE 8

WIND SPEED HOURLY FREQUENCY DISTRIBUTION
WS-2, JANUARY 1981

	Wind Speed, mph (% in given interval)						
Time	Calm	2	2-4	4-6	6-8	8-10	10
0-1	21	37	21	11	11		
1-2	30	25	25	10		5	5
2-3	16	42	21	11	11		
3-4	32	32	5	11	16		5
4-5	37	32	16	5	11		
5-6	32	32	16	5	11		5
6-7	26	26	21	16	5	5	
7-8	21	32	21	11	11		
8-9	16	26	16	21	16	5	
9-10	11	42	21	16	5		5
10-11	0	42	37	5	11		5
11-12	0	58	37			5	
12-13	0	58	32	5		5	
13-14	0	53	37		11		
14-15	0	47	37	5	5	5	
15-16	5	47	37		11		
16-17	37	37	16	5			5
17-18	47	42	5			5	
18-19	63	32				5	
19-20	63	21	5	5		5	
20-21	58	5	26		11		
21-22	42	11	26	5		16	
22-23	32	26	21	16	5		
23-24	21	32	16	26		5	
Avg.	25.4	34.9	21.5	7.9	6.1	2.8	1.3

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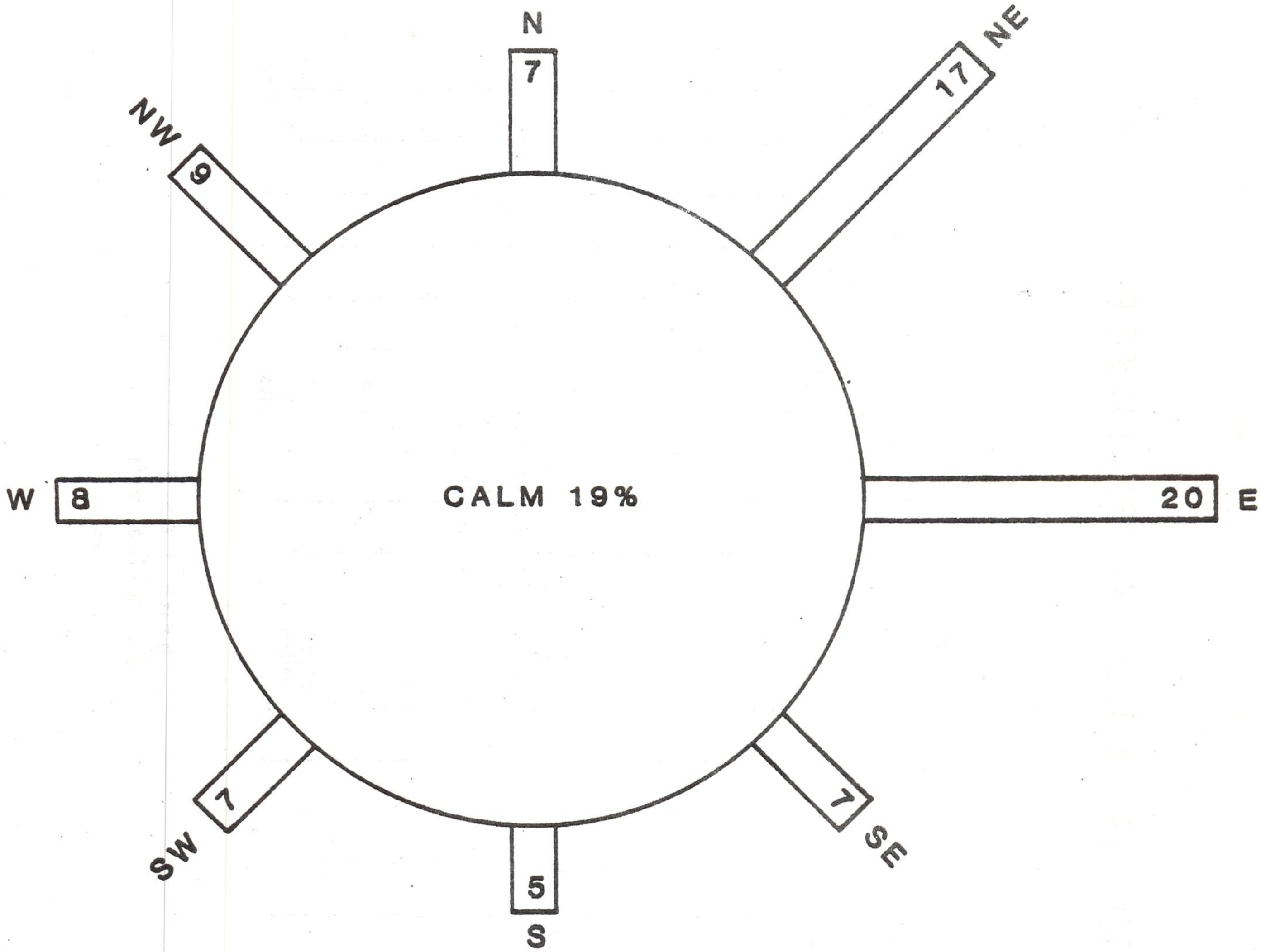
TABLE 9

FREQUENCY AND DURATION OF CALMS

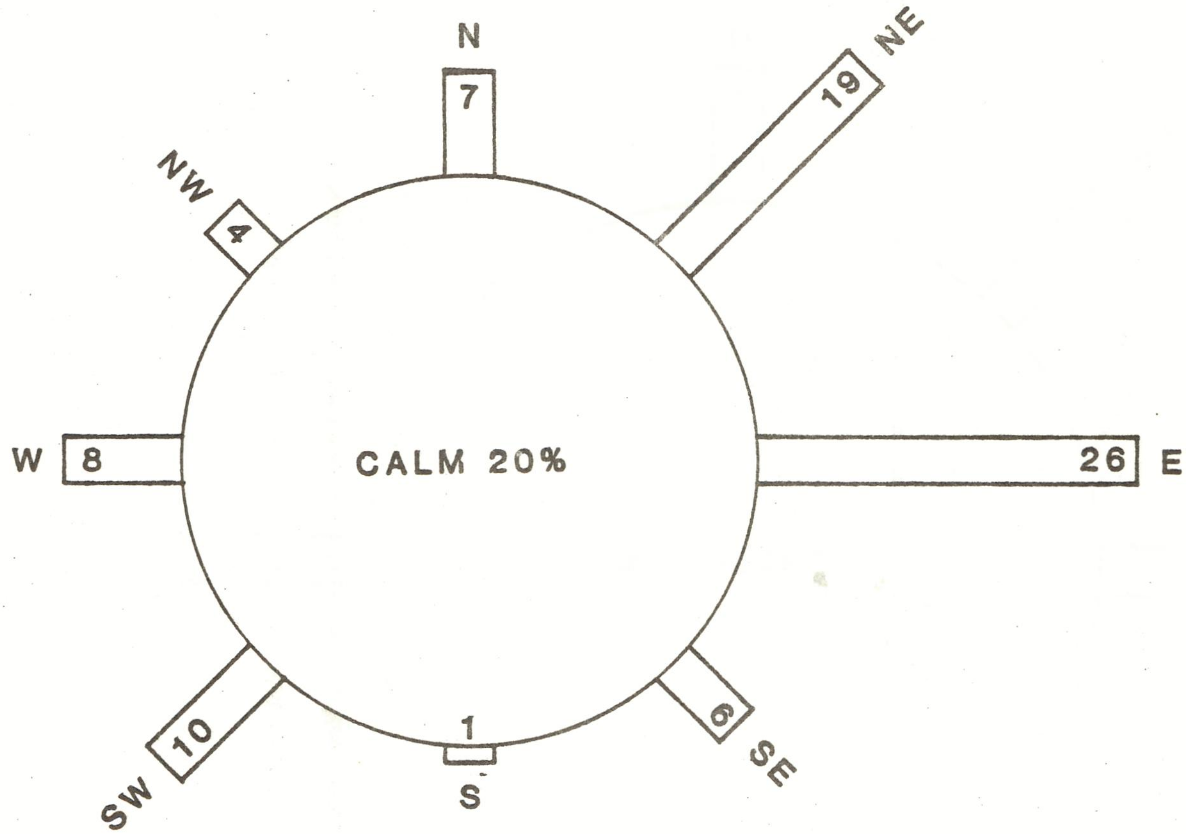
(%)

Duration (hrs)	December 1-31		January 1-15	
	WS-2	WS-3	WS-2	WS-3
1	44.5	47.8	41.9	40
2	20.8	17.4	9.7	20
3	13.9	15.2	22.6	30
4	6.9	4.4	12.9	0
5	5.6	2.2	3.2	5
6	5.6	4.4	6.4	0
7	1.4	0	0	5
8	1.4	2.2	3.2	0
9	0	6.6	0	0
Total Calm Frequency	27	19	25	15



(Percent of time wind blows from given direction)

FIG. 13 WIND ROSE (DECEMBER, 1980)



(Percent of time wind blows from given direction)

FIG. 14 WIND ROSE (JANUARY, 1981)

December to January, wind direction may not play a significant role in odor complaint conditions because most often complaints occur during calms. During calm conditions wind direction cannot be determined with the instrumentation.

$\underline{\Delta T}$

A typical ΔT trace is presented on Figure 15. Note that a positive ΔT occurs during evening and early morning hours while a negative or neutral ΔT prevails during daylight hours. Also superimposed upon the ΔT trace is an indication of the periods in which calms prevailed. Generally it appeared that under calm conditions a temporary increase in the sublayer temperature gradient occurred.

An hourly frequency distribution for PT conditions (ΔT greater than $2^{o}F$) is presented on Table 10. PT conditions rarely prevail during daylight hours and most frequently prevail during evening and morning hours. During the month of December, evening PT conditions were most likely to prevail between 1600 and 2000 hours. During the month of January, evening PT conditions were most likely to prevail between 1700 and 2300 hours. During the month of December, morning strong temperature inversions typically occurred between 0100 to 0700. During the month of January the most frequent occurrence of morning PT conditions was between 0500 and 0600 hours.

The PT frequency was greater both in terms of total time and in percentage of days in the month in which PT prevailed in December than it was in January. PT prevailed 14.6% of time and 63% of days for the days measured in December while it prevailed 6.7% of time and 44.5% of days during January. It should be noted that the data analyzed constitutes only one week in both December and January.

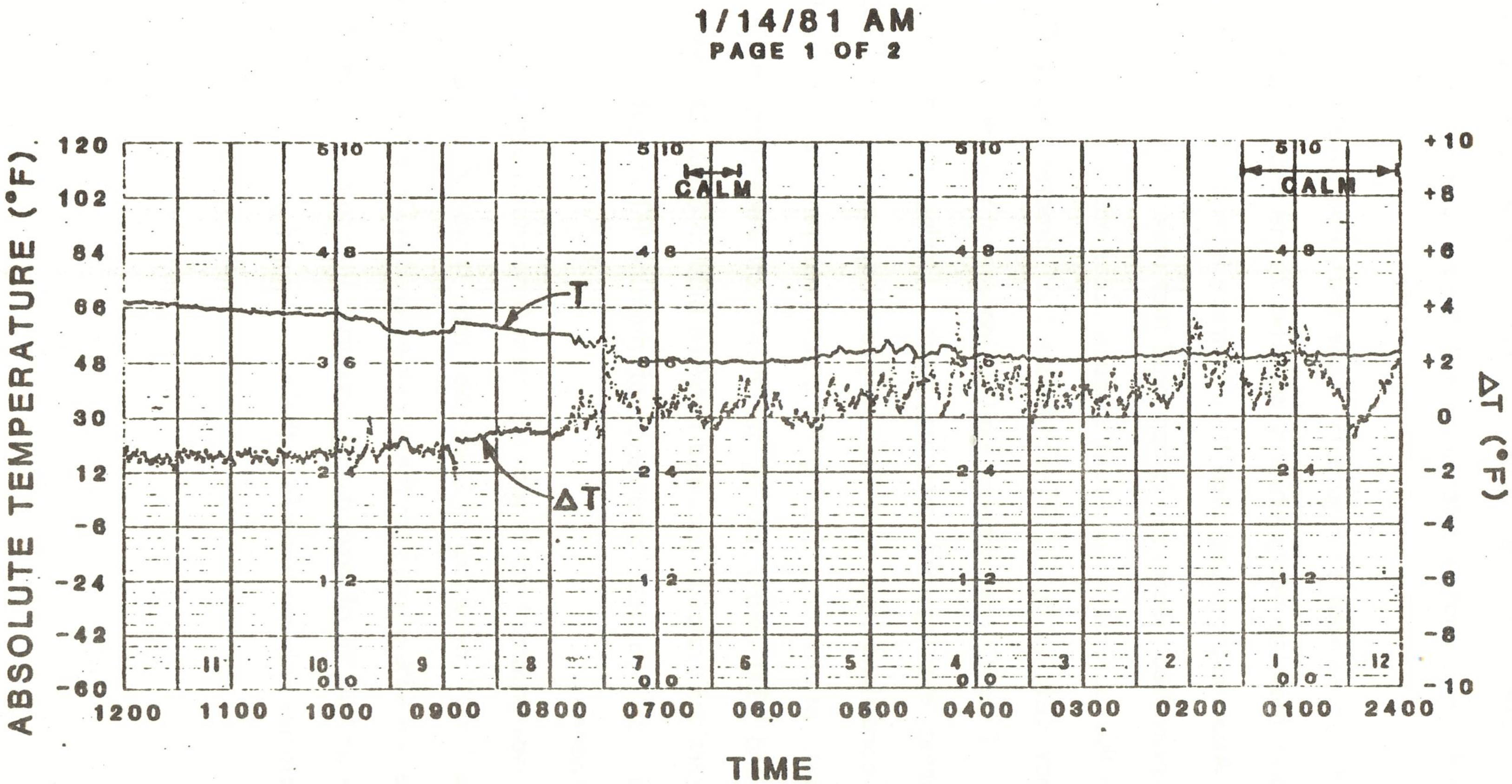


FIG. 15 TYPICAL ΔT TRACE

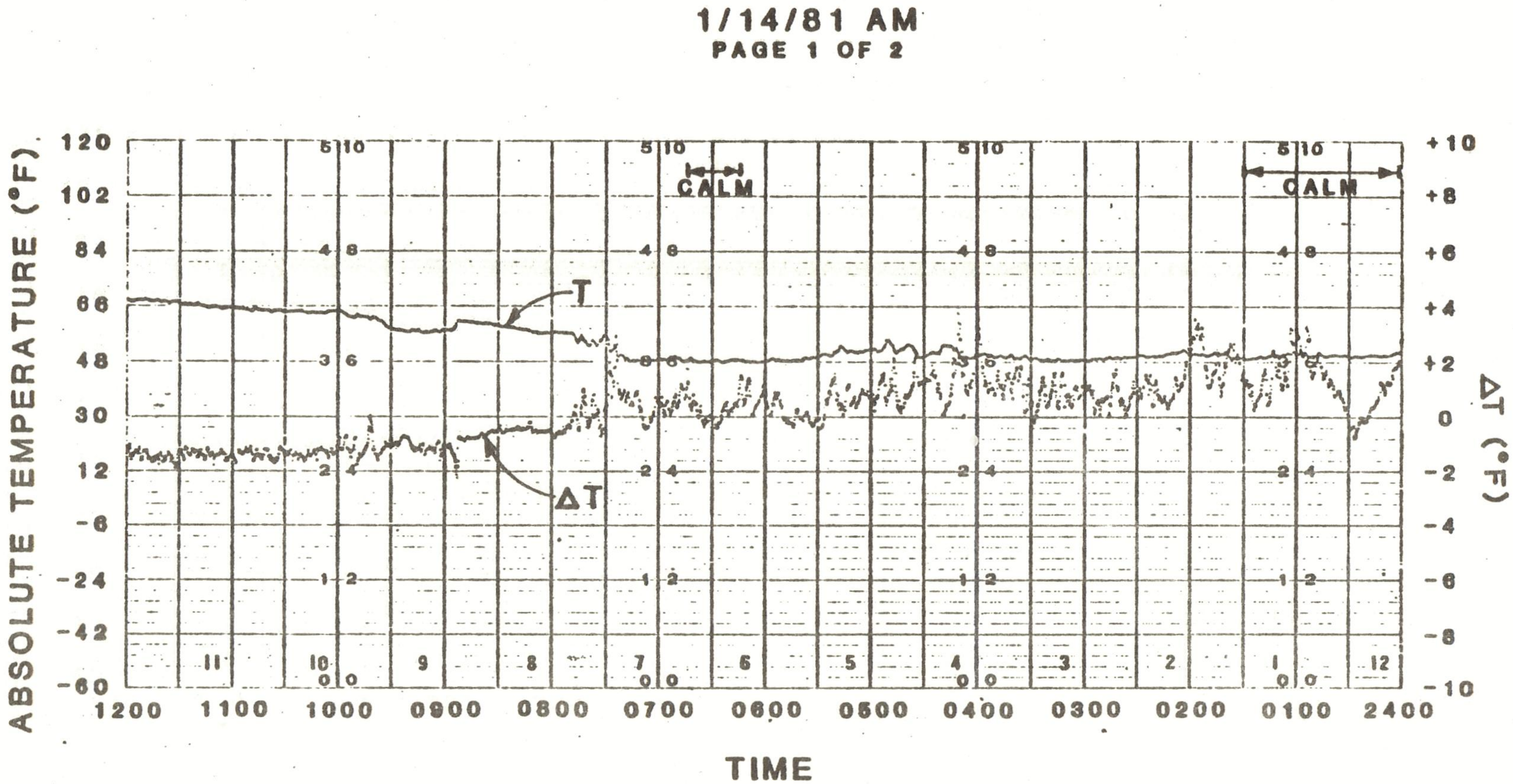


FIG. 15 TYPICAL ΔT TRACE

1/14/81 PM
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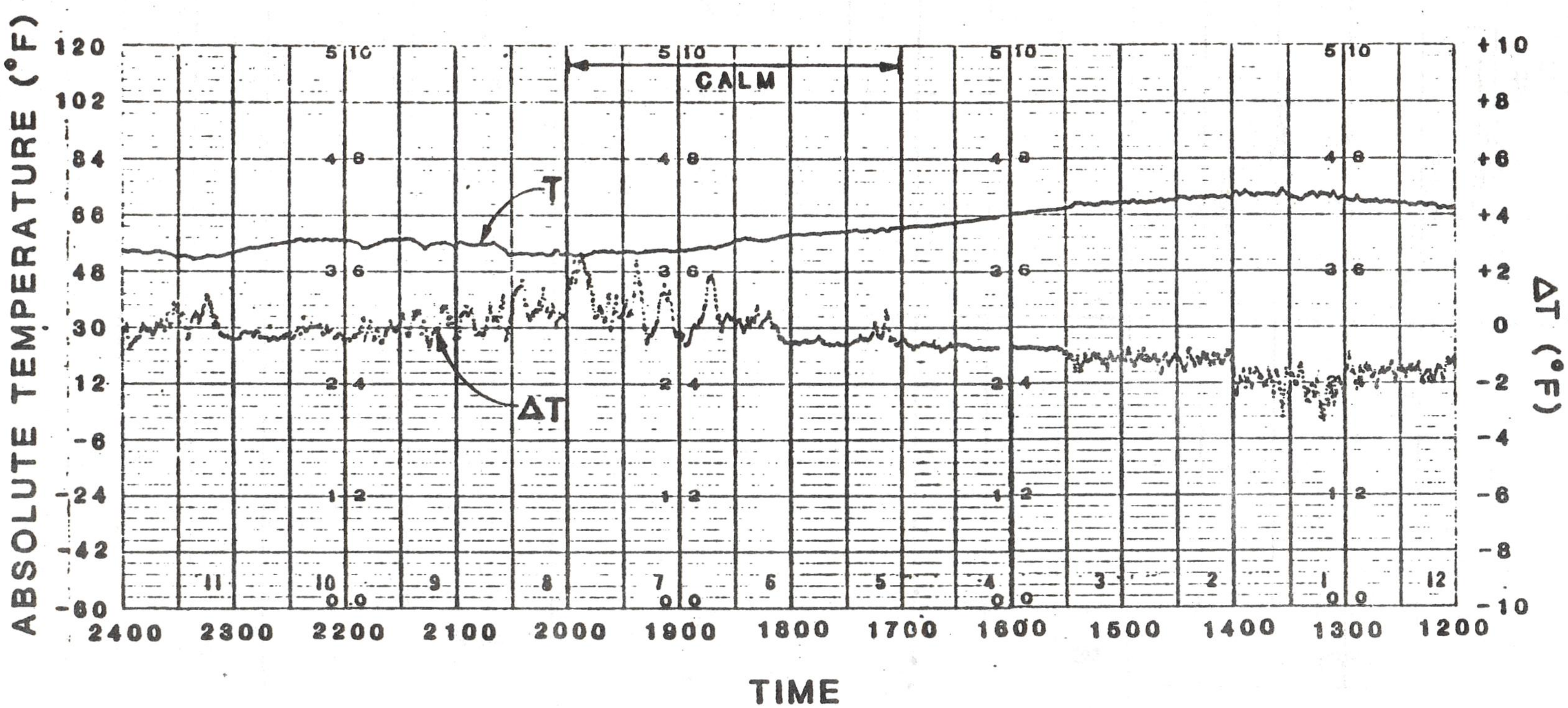

FIG. 15 (CONTINUED)

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TABLE 10

PT HOURLY FREQUENCY DISTRIBUTION

Time	Frequency of PT for Given Time (%) December 3 - 10[a]	January 6 - 14[a]
0100	25	5.6
0200	17	5.6
0300	30	5.6
0400	60	5.6
0500	22	16.7
0600	30	11.1
0700	11	5.6
0800	8	0
0900	9	0
1000	0	0
1100	0	0
1200	0	0
1300	0	0
1400	0	0
1500	0	0
1600	15	5.6
1700	7	11.1
1800	31	11.1
1900	21	11.1
2000	14	22.2
2100	0	16.7
2200	17	16.7
2300	8	11.1
2400	25	0
Daily	14.6	6.7
Percentage of days in Month	63%	44.5%

[a]The ΔT instrumentation utilized in December was different from that used in January.

Different instrumentation was used in December than was used in January. The instrumentation used in December was unreliable and had to be replaced. For that reason comparisons of ΔT between December and January cannot be given too much weight.

Net Radiation

Figure 16 shows a typical diurnal pattern of net radiation. The net radiation is positive during cloud-free daylight hours and is negative during evening hours. A negative net radiation indicates heat loss from the earth surface. The net radiation measurements are stable during the nighttime hours. Hourly frequency distributions for net radiation are presented in Table 11 and 12 for December 1980 and January 1981 respectively. January showed somewhat higher positive and negative net radiation than did December. Other than the extremes the frequency distributions were similar.

Temperature and RH

Figure 17 shows a typical diurnal temperature and RH recording for WS-2. The low temperatures were recorded during the early morning hours and high temperatures at approximately 14:00 hours. The lowest RH was recorded at the point of the highest temperature and the highest readings occurred at the points of lowest temperature.

The high and low RH and temperature for WS-2 for December and January are presented in Tables 13 and 14 respectively. The average high RH was 78% for December and 86% for January. The average low RH was 40% for December and 41% for January. The average high and low temperatures for December and January were identical.

Hourly frequency distributions for temperature and RH for the months of December and January are presented in Tables 15, 16, 17 and 18 respectively. As

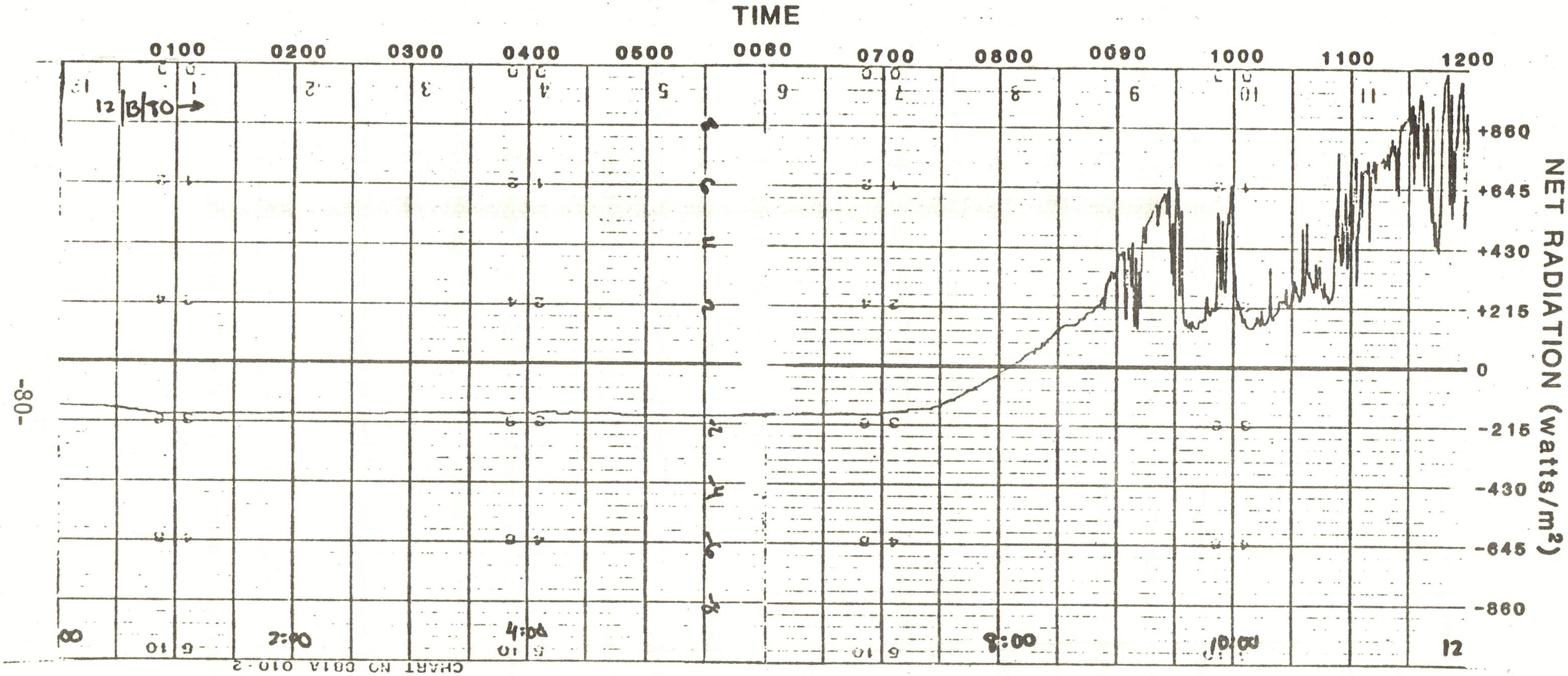

FIG. 16 TYPICAL NET RADIATION CHART

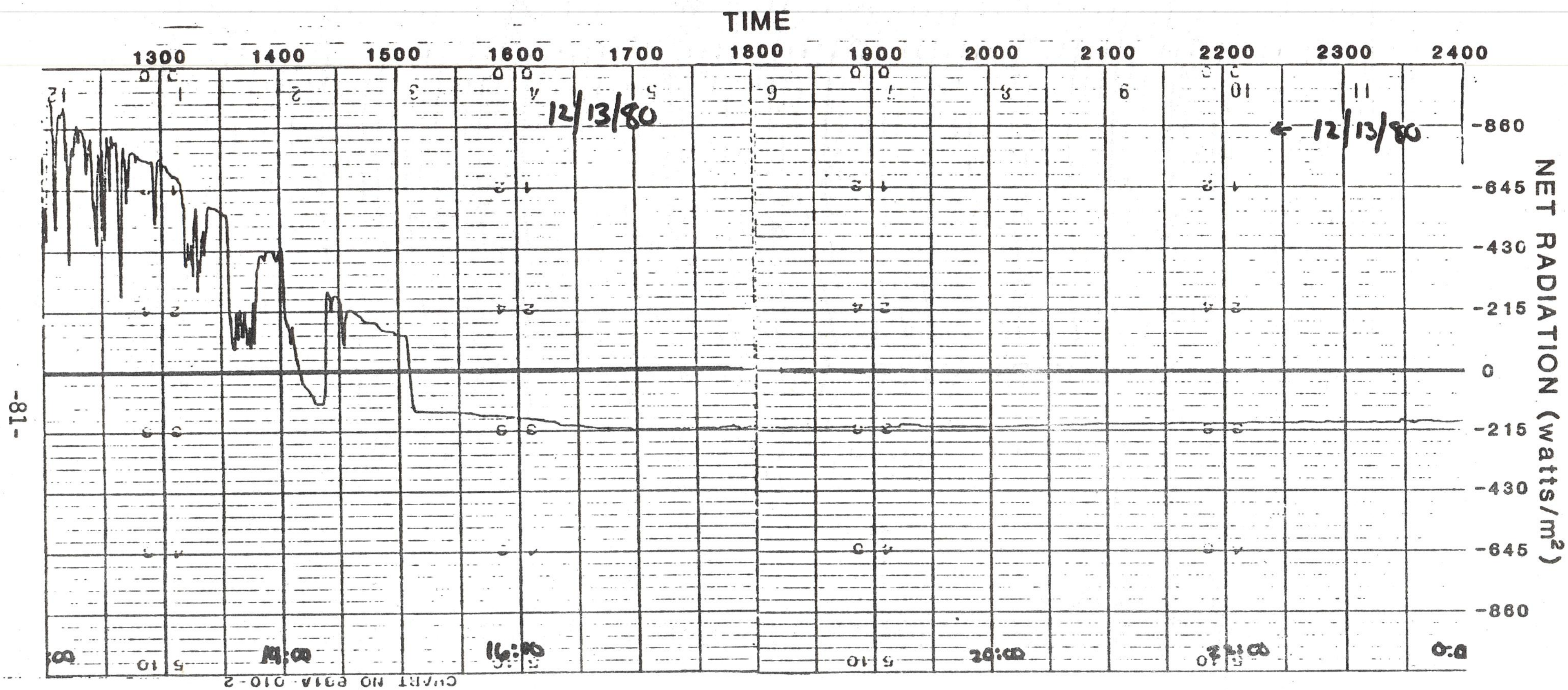

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FIG. 16 (CONTINUED)

TABLE 11

NET RADIATION HOURLY FREQUENCY DISTRIBUTION, DECEMBER 1-19, 1980

	Net Radiation, watts/m² (% in given range)												
Time	<-200	-200 to -100	-100 to 0	0-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	>900
0-1		53	47										
1-2		56	44										
2-3		56	44										
3-4		50	50										
4-5		39	61										
5-6		28	72										
6-7		33	67										
7-8		11	89										
8-9			6	50	11	28	6						
9-10				6	24	6	29	29	6				
10-11				6	6	6	6	19	19	31	6		
11-12							7		13	53	27		
12-13				6	12	12	6	6		53	6		
13-14					18	12	12	12	24	18	6		
14-15				6	19	19	38	13	6				
15-16			38	50	6	6							
16-17		13	87										
17-18		76	24										
18-19		63	37										
19-20		71	39										
20-21		65	35										
21-22		53	47										
22-23		53	41	6									
23-24		59	41										

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TABLE 12

NET RADIATION HOURLY FREQUENCY DISTRIBUTION, JANUARY 5-23, 1981

	Net Radiation, watts/m^2 (% in given range)												
Time	<-200	-200 to -100	-100 to 0	0-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	>900
0-1	9	27	64										
1-2	9	45	45										
2-3	10	40	50										
3-4	9	36	55										
4-5		45	55										
5-6	9	27	64										
6-7	9	27	64										
7-8	9		82	9									
8-9			27	27	18	27							
9-10				18		9	9	9	45		9		
10-11					18		18		9	36	18		
11-12							27			45	9		18
12-13								18	9	27	18	18	9
13-14				10			10	20	30	30			
14-15			8			42	33	17					
15-16		27	54	18									
16-17		55	45										
17-18		83	17										
18-19		69	31										
19-20		69	31										
20-21		69	31										
21-22		67	33										
22-23		50	50										
23-24		50	50										

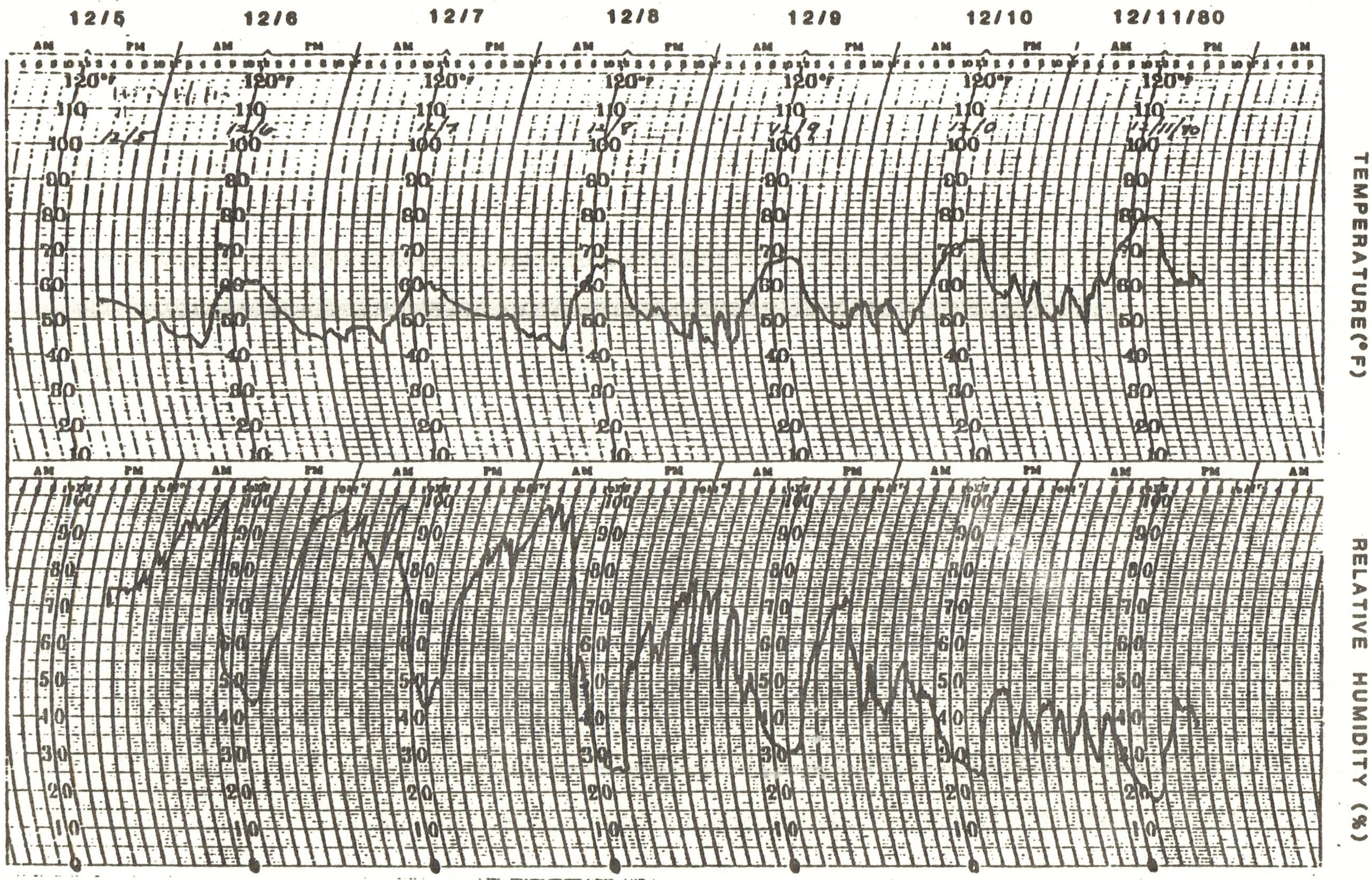

FIG. 17 TYPICAL TEMPERATURE AND RELATIVE HUMIDITY CHART
WEATHER STATION NO. 2, 12/5 - 12/11/80

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TABLE 13

HIGH AND LOW RH AND TEMPERATURE
WS-2, DECEMBER 1-19, 1980

Date	RH (%)		Temp (°F)	
	High	Low	High	Low
1	55	52	65	62
2	98	51	70	63
3	90	89	88	56
4	92	52	64	52
5	85	70	56	50
6	98	44	60	43
7	97	43	60	44
8	97	21	67	42
9	77	30	68	43
10	55	25	68	46
11	48	17	79	50
12	52	30	60	52
13	87	32	72	46
14	80	24	76	46
15	46	17	84	52
16	51	33	87	60
17	90	37	76	51
18	86	50	61	46
19	90	38	64	45
Avg.	77.6	39.7	69.7	50.0

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TABLE 14

HIGH AND LOW RH AND TEMPERATURE
WS-2, JANUARY 5-23, 1981

Date	RH (%)		Temp (^{o}F)	
	High	Low	High	Low
5	75	17	79	49
6	27	11	77	59
7	85	26	70	48
8	90	39	64	45
9	75	16	73	45
10	36	22	76	57
11	100	35	63	54
12	85	69	63	57
13	92	69	72	49
14	91	35	73	51
15	100	49	68	48
16	100	54	65	48
17	100	49	69	46
18	87	35	73	49
19	100	52	68	46
20	100	52	68	47
21	100	58	69	47
22	100	36	72	53
23	100	60	62	46
Avg.	86.5	41.3	69.7	49.7

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TABLE 15

TEMPERATURE HOURLY FREQUENCY DISTRIBUTION, WS-2, DECEMBER 1-19, 1980

Time	Temperature, °F (% in given range)									
	40-45°	45-50°	50-55°	55-60°	60-65°	65-70°	70-75°	75-80°	80-85°	>85°
0-1	6	25	25	19	25					
1-2		40	27	7	27					
2-3	13	25	25	13	19					6
3-4	18	24	18	18	24					6
4-5	6	39	22	6	17	6			6	
5-6	18	35	18	12	12				6	
6-7	24	24	12	12	18	6			6	
7-8	13	25	25	6	19	6			6	
8-9		27	7	33	20		7		7	
9-10		6	19	19	31	13	6		6	
10-11		6	12	18	18	24	6	12	6	
11-12			12	18	18	18	18	12	6	
12-13				25	13	19	13	19	13	
13-14				18	24	24		24	6	6
14-15				13	25	25	6	19	6	6
15-16				25	13	25	25			
16-17			13	44	25	6	13			
17-18		6	29	24	24	18				
18-19		19	31	19	25	6				
19-20		24	24	18	24	12				
20-21		19	38	19	25					
21-22		31	25	25	13	6				
22-23		20	40	20	13	6				
23-24		21	29	29	7	7				
Daily Average	4.3	18.9	19.1	17.9	19.4	9.1	3.3	3.6	3.1	1.2

TABLE 16

TEMPERATURE HOURLY FREQUENCY DISTRIBUTION, WS-2, JANUARY 5-23, 1981

Time	Temperature, °F (% in given range)									
	40-45°	45-50°	50-55°	55-60°	60-65°	65-70°	70-75°	75-80°	80-85°	>85°
0-1	6	29	24	29	12	6				
1-2		22	33	22	11	6				
2-3		24	35	24	18					
3-4		29	35	18	18					
4-5		29	35	24	12					
5-6		44	25	31						
6-7		33	33	27	7					
7-8		44	25	25	6					
8-9	6	18	29	29	18					
9-10	6	6	24	29	24	12				
10-11		6		35	29	12	18			
11-12			6	22	22	28	22			
12-13				8	18	33	22	11		
13-14				6	22	33	18	22		
14-15					25	37	25	13		
15-16					25	37	25	13		
16-17				13	47	33	20			
17-18			6	31	56	6				
18-19			28	39	33					
19-20		6	35	41	12	6				
20-21		22	39	22	11	6				
21-22		24	35	24	12	6				
22-23		25	25	31	13	6				
23-24		25	31	31	6	6				
Daily Average	1.1	16.9	21.8	23.3	17.4	11.4	6.2	2.0	0	0

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TABLE 17

RH HOURLY FREQUENCY DISTRIBUTION, WS-2, DECEMBER 1-19, 1980

Time	Relative Humidity (%) 0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100
0-1								6	13	19	13					19	19	13		
1-2								6	6	19	19		6		6		25	6	6	
2-3							6	13	13		13	6		13			13	13	13	
3-4							7	7	13	13	13		7	7	13			7	7	7
4-5							6		19	13	19				6		6	19	13	
5-6								13	6	6	13	13	6	6			6	25	6	
6-7							13		13	6	6	19	6				6	13	19	
7-8						6	6	6		25		13	6			6		19		13
8-9							6	6	19	6	6	19			6	6	6	13	6	
9-10						13	6	6	19	6	6	13		6	6	6	13			
10-11					6	6	19	13		13	6	13		13	6		6			
11-12					19	6	13	13	6	13	13		13		6					
12-13				13	6	6	19	13	13	6	13	6		6						
13-14				13	13	13	6	19	19	6	6	6								
14-15				13	13	6	13	25	6	13		13								
15-16				6	19	6	13	19		19	6	6								6
16-17					6		12	6	12	24	6	18	6		6	6				
17-18							6	6	6	12	6	24	12	6	24					
18-19								6	6	18	6	6	18	12	12	12	6			
19-20									24		12	6		6	12	6	18	12		
20-21							6	13	6	13	6			6	19		19	6	6	
21-22								13	13	13	6		6	13	13		6	25		
22-23							6	6	12	12	6	6		6	12	6	6	24		
23-24								6	18	18	6		6	6	6	6	12	12	6	
Daily Average	0	0	0	1.8	3.1	2.8	7.2	8.5	10.2	12.1	8.5	7.7	3.3	4.6	6.4	2.8	7.2	9.0	3.4	1.0

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TABLE 18

RH HOURLY FREQUENCY DISTRIBUTION, WS-2, JANUARY 5-23, 1981

Time	Relative Humidity (%)																			
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100
0-1					5	5	5	5					5	11	11	5	16	5	11	16
1-2					5	5	5	5			5	5				5	11		16	21
2-3				5		5	5	5			5	5			11	5	16	11	5	21
3-4				5			11			5	5			5	11	16		15		26
4-5				5			11						5	11	5	16	11	5	5	26
5-6				5			11				11		11			5	11	11	11	26
6-7					5		5	5	5	11		5				5	5	15	16	21
7-8					5		16			5		5		11		5	5	16	5	26
8-9					5	5	5	5		5	5		11	5		11	5	11		26
9-10					5	5	5	5	5	5	11			11	5	5	5	11	11	11
10-11				5		16		11	5	5		16		5	11	11	5	5		5
11-12			5		11	5		16		11	11	11		16	5	5			5	
12-13			5	11	5		11	5	5	11	26			11			5	5		
13-14			11	5	5		16			11	21	11	5	5			11			
14-15			5	11	5			16	5	16	11	16	5			5	5			
15-16			5	11	5			5	5	16	11	11	16	5	11					
16-17			5		5	5	5		5	5	5		16	16	5		5		5	
17-18			5			5	5	5			5		11	16	21	11		5	5	5
18-19					5		5	5	5				5	16	16	5	11	11		16
19-20						5	5		11					16	11	16	5	11	11	16
20-21					5	5	5		5					11	11	11	5	16		26
21-22					5		11		5					16		11	11			26
22-23					11		5	5						16	11	5	11	5		32
23-24					11		5	5					5	11	5	11	11		5	32
Daily Average	0	0	1.8	2.6	4.2	2.9	6.4	5.1	1.8	4.6	5.5	4.4	4.0	8.8	7.3	6.8	6.6	6.6	5.1	15.7

indicated by the tabulation of high and low temperature and RH, there was little difference between December and January in temperature but there was a definite increase in RH in January over December. This increase could account for a decrease in the strength of inversions in January and some improvement in downwind odor conditions.

DOWNWIND ODOR: LOCATIONS, OCCURRENCES AND CONCENTRATIONS

Downwind odor monitoring was carried out in two three-week intervals. The first period began on December 1 and ended on December 19, 1980. The second period began on January 5, 1981 and ended on January 23, 1981. Monitoring was completed over two separate intervals in order to determine whether any improvement had been made. Monitoring took place between approximately 3:00 pm to 11:00 pm on Monday thru Friday. This monitoring period was chosen because it was historically the time when the greatest number of odor complaints occurred.

Measured odor concentrations for both complaint responses and general surveillance of the neighborhoods are presented on Table 19. Table 19 also includes the results of the simultaneous paired tracer results and an indication of the prevailing micrometeorology at the time of the measurement. Odor concentrations measured in response to complaints ranged from concentrations too low to be measurable by the DRO but yet detectable to the nose to odor concentrations up to 50 ou/cf. Most measurable concentrations ranged between 4 to 10 ou/cf, with a median concentration of 6 ou/cf.

Whereas an odor concentration at its MDTOC is by definition detectable, it is usually not sufficient to result in odor complaints. Previous studies have established that odor concentrations in excess of 5 ou/cf are easily detectable and can result in odor complaints. An odor concentration of 5 ou/cf has been determined to be the threshold complaint level. As odor concentrations increase to

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TABLE 19

PAIRED ODOR AND TRACER CONCENTRATION MEASUREMENTS

Date	Time	Measurement Location	Odor Conc. (ou/cf)	SF_6 Conc. (ppb)	x (ft)	$K^1(Y)^{1/2}$ ($ft^{5/2}$/min)	Q Odor (10^6 ou/min)	ΔT (°F)	u (mph)	Θ (°N)	Temp (°F)	RH (%)	Tracer Location
12/2	21:20	Marlena @ Nogales	5	1.0	---	---	27	0.0	---	---	---	---	
12/2	21:20	Marlena @ Nogales	5	0.12	---	---	228	---	---	---	---	---	
12/2	21:44	300 ft. W. of Nogales	8	1.7	---	---	26	---	---	---	---	---	
12/4	21:23	1930 Cumberland	0	0.04	5400	1.86×10^6	---	0.0	---	---	---	---	K-12
12/4	21:35	2704 Miranda	0	0.08	1700	1.66×10^6	---	-0.5	---	---	---	---	K-12
12/5	21:55	Kings Crest @ South Hills	2	0	5800	---	---	0.0	1.0	140	51	78	K-12
12/8	18:22	2349 Lynn Ct.	2	0	2500	---	---	4.5	0.00	340	54	57	K-12
12/8	18:48	Melissa & Marcella	6	0.087	1400	1.68×10^6	377	2.8	0.00	340	50	65	M-12
12/8	19:00	Mary @ Marlena	10	0.12	1800	1.08×10^6	456	0.7	0.5	210	50	65	M-12
12/8	21:30	End of Nogales	4	0.04	1400	3.66×10^6	547	0.7	1.0	175	52	62	M-12
12/8	22:10	Nogales @ Marlena	6	0.044	1800	2.93×10^6	746	1.5	0.5	260	50	62	M-12
12/8	22:25	Amar @ Paseo Merida	2	0	2200	---	---	1.5	0.5	260	50	62	M-12
12/9	18:08	Paseo Tepic	0	0.18	4200	4.69×10^5	---	4.9	0.00	288	48	50	M-3
12/9	18:24	226 Marlena	0[a]	0.13	3200	7.44×10^5	---	4.9	0.00	288	48	50	M-3
12/9	18:30	Marlena/600ft. W of Nogales	3	0	3100	---	---	2.7	0.00	288	48	50	M-3
12/9	18:36	N. end Lorraine	0[a]	0	3800	---	---	2.7	0.00	288	48	50	M-3
12/9	18:47	Amar @ Mary	6	0.25	3600	3.65×10^5	131	2.7	0.00	288	50	65	M-3
12/9	20:35	2550 Marlena	6	0.095	3200	1.02×10^6	346	3.0	0.00	315	56	49	M-3
12/9	20:40	2611 Marlena	6	0	3200	---	---	3.0	0.00	315	56	49	M-3
12/9	21:27	2602 Mary Ct.	8[a]	0	3500	---	---	1.6	0.00	315	64	44	M-3
12/10	16:15	Nogales @ Marlena	10	4.0	1100	4.13×10^4	14	---	0.5	335	60	32	N-15
12/10	20:25	End of Lynn Ct.	10	0.75	2500	1.46×10^5	73	---	2.5	97	61	40	N-15
12/10	20:40	End of Nogales	8	0	800	---	---	---	2.5	97	60	40	N-15
12/10	22:20	Lynn Ct. @ Nanette	4[a]	0.3	2600	3.58×10^5	73	---	1.5	75	70	36	N-15
12/11	17:30	2724 Miranda	8[a]	0	1200	---	---	---	0.00	279	---	---	N-15
12/11	17:42	Marlena @ Mary Ct.	8	2.4	1000	7.21×10^4	18	---	0.00	279	---	---	N-15
12/11	20:40	End of Lynn Ct.	10[a]	0	2400	---	---	---	2.0	140	---	---	N-15
12/11	20:47	Nanette/bet. Lynn & Leanna	6[a]	0	2900	---	---	---	2.0	140	---	---	N-15
12/11	21:32	2550 Marlena	10[a]	1.2	1100	1.38×10^5	46	---	0.00	27	---	---	N-15

a = Complaint response.

Continued on next page

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TABLE 19 (Cont.)

PAIRED ODOR AND TRACER CONCENTRATION MEASUREMENTS

Date	Time	Measurement Location	Odor Conc. (ou/cf)	SF_6 Conc. (ppb)	x (ft)	$K^1(Y)^{1/2}$ ($ft^{5/2}$/min)	Q Odor (10^6 ou/min)	ΔT (°F)	u (mph)	Θ (°N)	Temp (°F)	RH (%)	Tracer Location
12/11	22:35	Marlena & Mary	15	3.6	1000	4.81×10^4	23	---	0.00	279	---	---	N-15
12/12	18:12	Lynn Ct. Turnaround	6	---	2000	---	---	---	0.00	calm	---	---	J-12
12/12	18:38	2613 Paseo Olivas	8[a]	---	2300	---	---	---	0.00	calm	---	---	J-12
12/12	20:20	Lynn Ct. Turnaround	6	0	2000	---	---	---	2.0	36	---	---	J-12
12/12	20:46	Manette & Lisa	6	0.027	2700	3.9×10^6	1216	---	0.00	calm	---	---	J-12
12/12	20:50	W. Mannette Turnaround	6	0.27	2400	4.14×10^6	122	---	0.00	calm	---	---	J-12
12/12	21:40	Lynn Ct. Turnaround	3	0.056	2000	2.19×10^6	293	---	3.0	55	---	---	J-12
12/15	18:35	Miranda & Marcella	6	0	2500	---	---	---	0.00	calm	---	---	F-13
12/16	17:36	Lynn Ct. Turnaround	5	---	1100	---	---	---	0.00	calm	70	38	F-15
12/16	18:45	Lynn Ct. Turnaround	5	0.07	1100	1.52×10^6	391	---	0.00	calm	67	38	F-15
12/16	20:00	Nogales @ Amar	4	0.05	2100	1.54×10^6	438	---	0.00	calm	63	45	F-15
12/16	20:10	Marcella @ Melissa	7	0	2300	---	---	---	0.00	calm	65	40	F-15
12/16	20:28	2611 Marlena	7	0	3000	1.54×10^6	438	---	0.00	calm	63	56	F-15
12/16	21:15	Leanna @ Lorraine	6	0	1600	---	---	---	0.00	calm	62	55	F-15
12/17	17:25	Lynn Ct. @ Mannette	7[b]	---	1400	---	---	---	0.00	calm	64	---	F-15
12/17	18:17	2606 Pase Olivas	6[b]	0	1900	---	---	---	0.00	calm	60	67	F-15
12/17	18:30	Nogales @ Amar	30[b]	0	2100	---	---	---	0.00	calm	58	68	F-15
12/17	18:52	2626 Marlena	30[b]	0	3000	---	---	---	0.00	calm	59	68	F-15
12/17	19:15	Marlena & Mary Ct.	50[b]	0	1900	---	---	---	0.00	calm	57	76	F-15
12/17	20:59	2611 Mary Ct.	15[b]	0.025	2000	3.16×10^6	3284	---	0.00	calm	53	82	F-15
12/17	21:12	2704 Miranda	30[b]	0.011	3600	5.35×10^6	14928	---	0.00	calm	54	88	F-15
12/17	21:34	Marlena @ Marcella	30[b]	0.04	2400	1.80×10^6	4105	---	0.00	calm	53	94	F-15
12/17	22:00	Miranda @ Marcella	30[b]	0	2200	---	---	---	0.00	calm	55	100	F-15
12/18	17:47	Marcella & Miranda	10	0	1900	---	---	---	2.0	230	55	82	G-16
1/5	18:10	2349 Lynn Ct.	6	0.08	3800	---	---	---	0.00	calm	60	39	M-3
1/5	21:00	2526 Marlena	7	0.05	3100	---	---	---	0.00	calm	62	50	M-3
1/6	18:25	Marlena & Marcelle	6	0	1600	---	---	+2.0	0.00	calm	66	36	M-12
1/9	18:00	2724 Melissa	6	---	2100	---	---	+2.0	0.00	calm	64	37	I-17
1/9	18:15	Miranda & Marcella	10	---	1700	---	---	+2.0	0.00	calm	62	44	I-17
1/13	20:20	Miranda (mid-street)	6	0.1	1000	1.1×10^6	---	+0.5	0.00	calm	53	89	
1/20	20:25	2526 Marlena	2	0	2000	---	---	+0.3	0.00	calm	50	100	
1/20	20:38		2	1.5	2200	5.0×10^4	---	+0.4	0.00	calm	52	100	
1/20	21:10		0	0.32	2500	2.2×10^5	---	+0.9	1.0	27	53	100	

[a] Complaint response.
[b] Broken gas line reported by BKK.

Note: QSF_6 = 155 cc/min on 12/2 to 12/12, 100 cc/min 12/15 to 1/19.

10 ou/cf, the psychological stress caused by the distracting effect of the odor's presence will consistently result in the occurrence of odor complaints. A concentration of 10 ou/cf has been identified as the odor complaint concentration.

The concentrations of odors measured in the neighborhoods surrounding the BKK Landfill have fallen within the range that would be expected to result in odor complaints. It should be noted, however, that the elusive nature of odors sometimes prevents confirmation of an odor complaint condition just minutes after a complaint is logged.

During the course of the odor study, several observations were made regarding occurrences of detectable odors. The first was that odors tended to concentrate or collect in low, cold air spots. One such area was in the vicinity of Amar and Nogales. The second was that the odors were elusive. The majority of odor complaints occurred during evening hours when the air was very still and stable. During this time sudden and dramatic changes in wind direction occurred which moved odors about or completely dispersed them within a few minutes.

A summary of the number of odor complaints received versus day of the month has been presented on Table 20. Most complaints originated from the M street area of West Covina. Some complaints occurred from the L street area. Only a very small number of complaints occurred north and west of the landfill. The M street area accounted for 2/3rds of all confirmed and measureable odor concentrations. The L street area accounted for 22% of confirmed and measureable odor concentrations.

The number of complaints received per day during the monitoring period ranged from a high of 25 to a low of zero. Complaints averaged 10.4 per night for

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TABLE 20

ODOR COMPLAINT HOT LINE SUMMARY

Date	No. of Complaints	No. of Responses	No. of Odor Measurements	Range of Odor Conc. (ou/cf)	Area of Complaints	Comments
12/1/80	25	5	5	3-10	"L" & "M"	
2	7	1	2	5-8	"M"	
3	0	0	0	--	—	Rain
4	3	2	2	none detected	"L" & "M", Cumberland	
5	1	1	2	1	South Hill Dr.	
8	11	7	6	2-10	"L" & "M"	
9	16	8	5	3-7.5	"L" & "M"	
10	12	6	4	4-10	"L" & "M"	
11	11	7	6	6-15	"L" & "M"	
12	14	9	6	3-8	"L" & "M"	
15	10	1	1	6	"L" & "M"	
16	13	11	6	4-7	"L" & "M"	
17	19	14	9	6-50	"L" & "M"	Gas line broken
18	1	1	1	10	"L"	
19	13	2	0	--	"L" & "M"	
Subtotal	156	75	54			
1/5/81	6	6	2	6-7	"L" & "M, Hidden Valley	
6	1	1	2	0-6	"M"	
7	4	3	1	none detected	"L" & "M"	
8	4	3	0	--	"M"	
9	7	1	2	6-10	"M"	
12	3	2	0	none detected	"L"	
13	9	4	1	6	"L" & "M"	
14	—	—	—	--	—	Radio communication out of order
15	—	—	—	--	—	Radio communication out of order
16	2	0	0	--	"L" & "M"	Odor crew doing SOER measurements
19	25	0	0	--	"L" & "M"	Gas drilling, odor crew doing SOER measurements
20	16	6	2	2	"L" & "M"	
21	6	0	0	--	"L" & "M"	Odor crew doing SOER measurements
22	1	1	0	2	"L"	Rain
23	1	1	0	2	"M"	
Subtotal	85	28	10			

the December study period vs. 6.5 per night for the January study period. In December responses were made on 48% of the complaints while in January responses were made on 33% of the complaints. A total of 54 downwind odor measurements were made in December vs. 10 downwind odor measurements in January.

The total number of complaints received during the on-site EUTEK study during January was significantly less than received during December (85 vs. 156). Furthermore, 72% of complaints in which responses were made were confirmed with measurable odors in December while 36% were confirmed with measurable odors in January. On a normalized basis, approximately 3.6 odor measurements with concentrations greater than 2 ou/cf were completed per study night in December compared to approximately 1.0 measurements per study night in January. In both December and January (excluding abnormal odor concentrations resulting from accident) the median downwind odor concentration was approximately 6 ou/cf.

The fact that fewer confirmed complaints occurred in January than in December could be due to one or more of the following:

1. Changes in micrometeorology.
2. Changes in dispersion.
3. Odor control measures implemented by BKK.

The following sections will discuss the probable impact that each of the above factors have had on downwind odor concentrations in December vs. January.

<u>Micrometeorology</u>

An analysis of the six micrometeorological parameters was completed in order to determine changes that occurred between December and January which could in part explain differences in the frequency of downwind detectable odors.

It should be noted that micrometeorology is never the same, even from moment to moment. Comparisons can be made based on averages and significant changes in frequency distributions.

Wind Speed. The frequency of calms remained approximately the same during the months of December and January (Tables 5-8). Both the total time in which calms prevailed and in the number of days in which calms occurred were similar. Thus it does not appear that wind speed can account for the changes noted.

Wind Direction. As shown on Figures 13 and 14 the wind direction distribution was different in December than it was in January. The true wind movement direction could not be recorded during calm periods. Because calms generally prevail during recorded odor complaints, the wind direction distribution during other than calm periods may not be an important factor.

ΔT. Because a change in instrumentation was made between December and January it was not possible to accurately determine the impact of this parameter on downwind odor conditions. If there were a reduction in the frequency and severity of ground level inversions this could in part explain the reduction in the number of confirmed and measurable odor conditions.

Net Radiation. Little change appeared to have occurred in nighttime net radiation between December and January (Tables 11 and 12). However, small changes in this parameter may have occurred and were not detected due to resolution limits of the instrument.

Temperature. The temperature frequency distribution and minimum and maximum values were on the average the same during December and January (Tables 13-16). Thus temperature cannot account for the changes noted.

RH. RH was on the average higher in January than in December. RH is important in the heat balance of the earths surface. The strongest inversions occur with low RH. The fact that RH was higher in January could in part explain some decrease in downwind odor conditions because inversion strength may not have been as great. RH was the only recorded meteorological parameter that showed significant change between December and January.

Dispersion

Downwind tracer concentration profiles were measured in December and January. These results, expressed in terms of the apparent PT diffusivity for the peak concentration, have been plotted on Figure 18. No significant changes in dispersion occurred between the two months. The observed reduction in downwind odor concentrations does not appear to be explained by increases in dispersion in January relative to December.

Odor Control Measures

Actions taken by the BKK Corporation which may have had an affect on the total number of occurrences in downwind odor concentrations included the following:

1. Shut down of the acid disposal wells.
2. Elimination or rejections of odorous waste loads.
3. Placing of additional fill and grooming of slopes.
4. Expansion of gas recovery system.

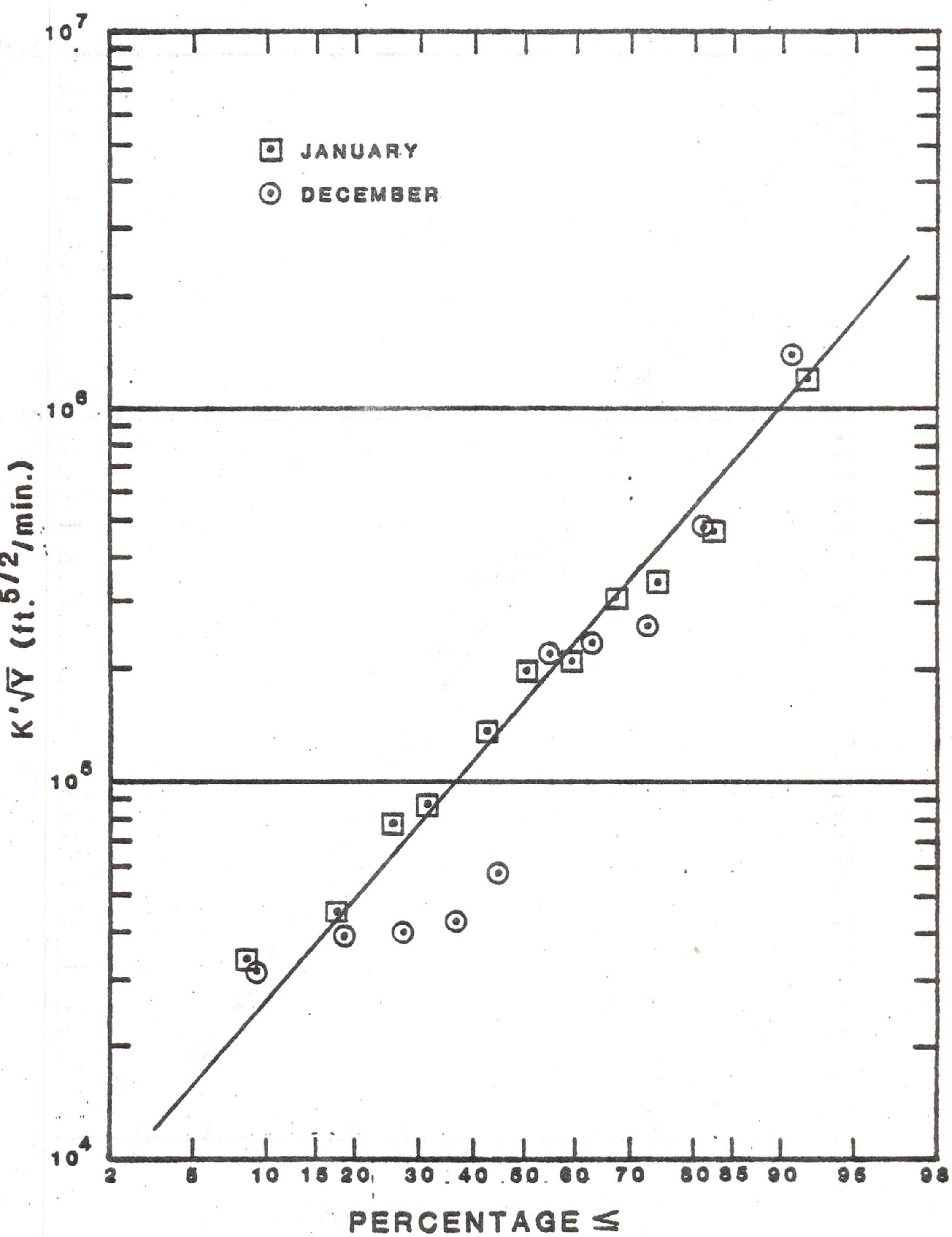

FIG. 18 FREQUENCY DISTRIBUTION OF $K'\sqrt{Y}$ DEC. vs JAN.

Acid Well Shutdown. Shutdown of the acid wells occurred prior to initiation of the odor study field work on December 1, 1980. The reduction in number of odor complaints in January over December could be explained in part by this action if the acid wells were a major source of odors and if the response time to the shutdown of the acid wells was on the order of approximately one month.

Rejection of Odorous Materials. The rejection of odorous loads was initiated prior to December 1, 1980. This action may have had an effect on the number of recorded complaints during the months of December and January.

Additional Cover. The placement of additional fill and subsequent grooming of slopes may have reducted the total site odor emissions. Grooming of the slopes would temporarily repair surface and settlement cracks which would prevent the direct escape of landfill gas. Fresh unsaturated soil has limited capacity for adsorption of odors. Once the adsorption capacity is utilized however, it would be expected that the high level of odor emissions could resume. The placement of fill and grooming of slopes occurred throughout the study period.

Gas Recovery. Seven additional gas recovery wells were placed in operation on January 14, 1981. This occurred mid-way through the January evaluation. Additional gas recovery may have reduced site odor emissions after January 14. Surface monitoring in the vicinity of the gas wells indicated a temporary decrease in the unit area surface odor emission rate (SOER).

A decrease in the number of confirmed and measurable downwind odor concentrations occurred between December and January. Based on comparisons of the pertinent parameters it appeared that the decrease could be explained by a reduction in site odor emissions and by changes in micrometeorology. The reduction in site odor emissions was probably due to the combination of odor control measures implemented by BKK Corporation. The only significant monitored change in micrometeorology was RH. RH was higher on the average in January than it was in December. This could account for a reduction in the frequency and intensity of ground level inversions which would reduce the frequency and severity of downwind odor conditions.

SITE ODOR EMISSION RATE

The apparent site odor emission rate was determined utilizing simultaneously paired downwind tracer and odor concentration measurements. Results have been summarized on Table 19. If the tracer were placed at the same location as the source of odors, then the apparent site odor emission rate could be computed with knowledge of the tracer emission rate, downwind tracer concentration, and downwind odor concentration using procedures outlined in Chapter IV.

A frequency distribution of the apparent site odor emission rate is presented on Figure 19. The paired tracer and odor concentration measurements were utilized to calculate the apparent diffusivity $(K'(Y)^{1/2})$. A frequency distribution of the apparent diffusivity is presented in Figure 20.

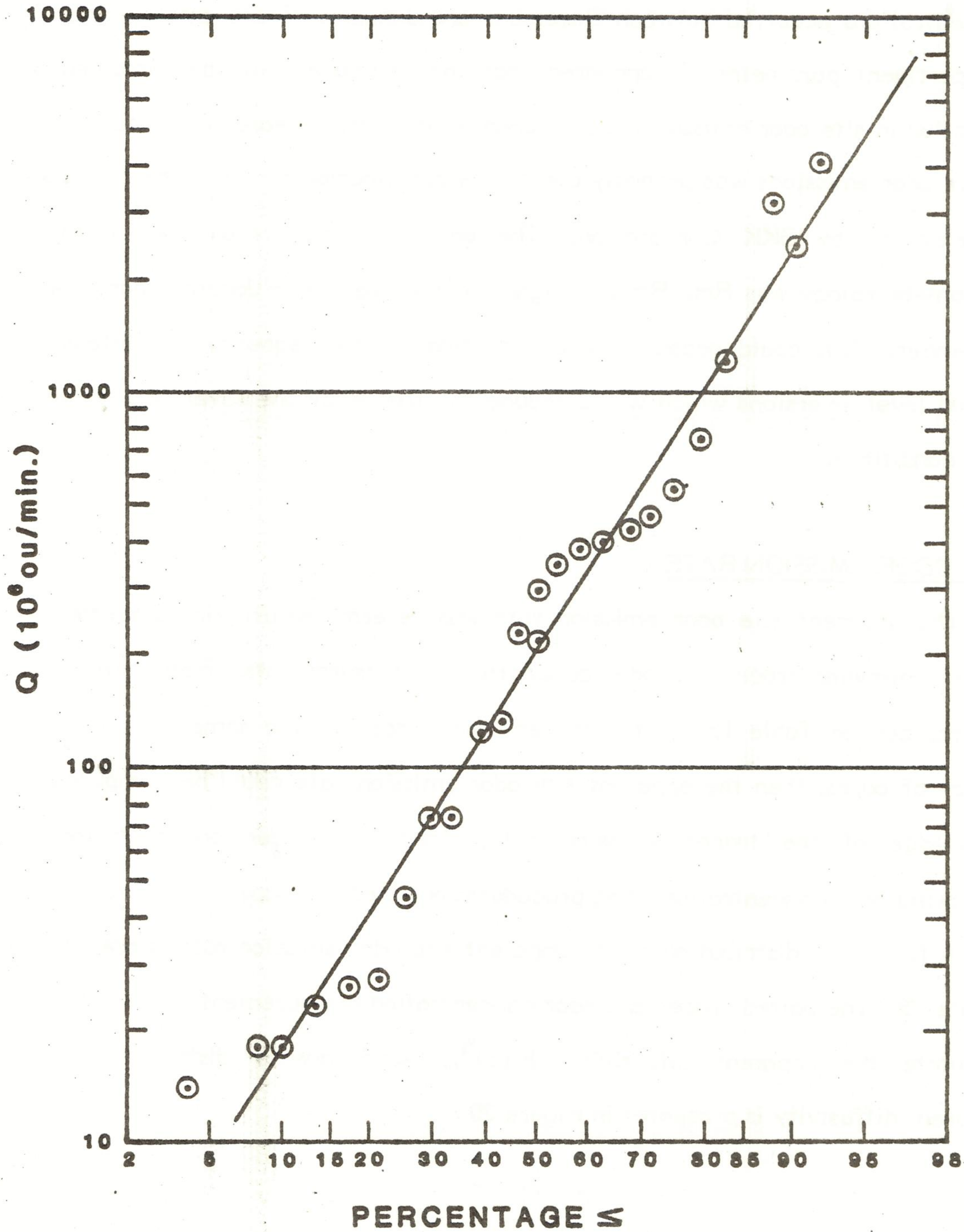

FIG. 19 APPARENT ODOR EMISSION RATE FROM PAIRED TRACER AND ODOR CONCENTRATION MEASUREMENTS

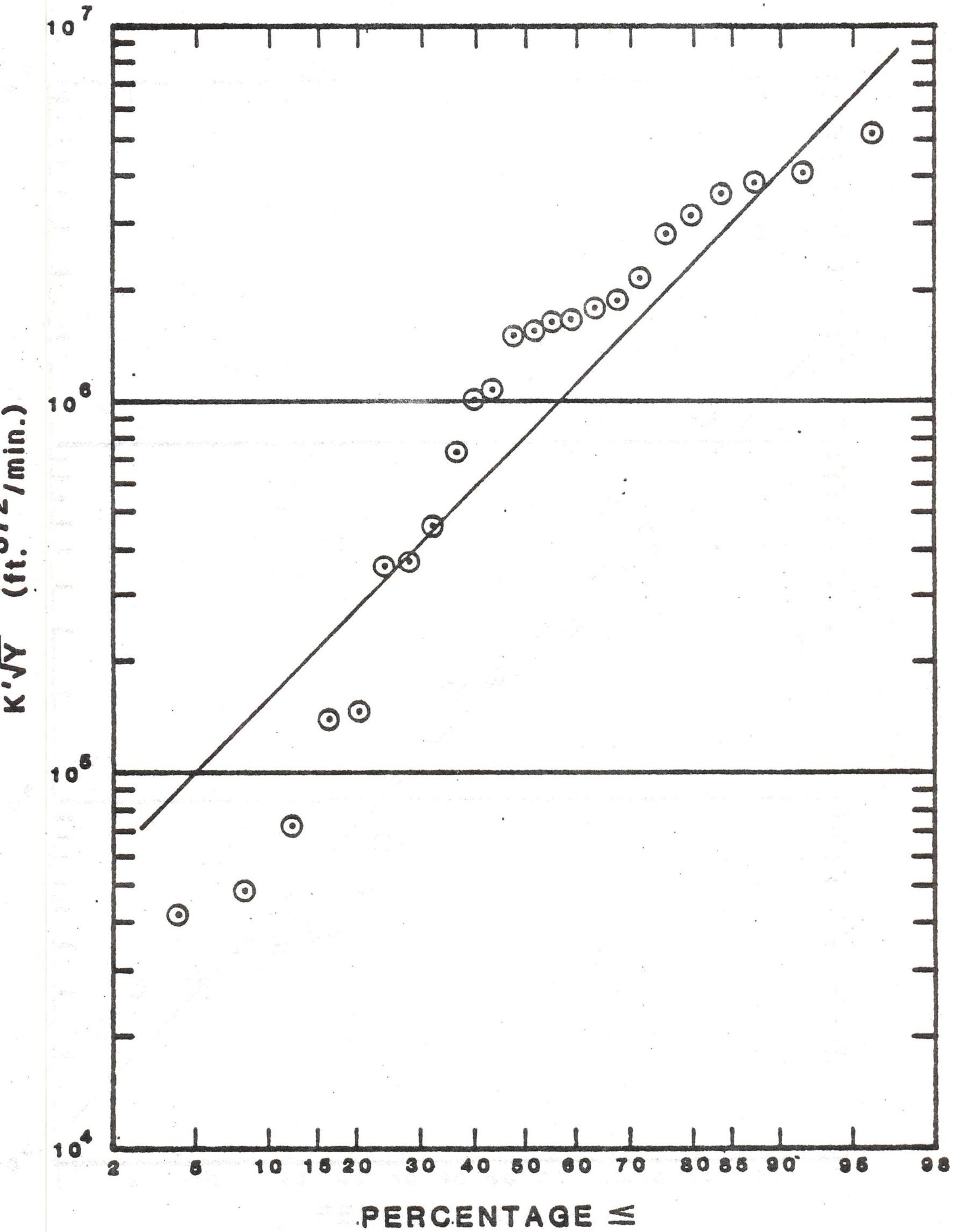

FIG. 20 FREQUENCY DISTRIBUTION OF $K'\sqrt{Y}$ FOR PAIRED ODOR AND TRACER MEASUREMENTS

Independent measurements of peak downwind tracer concentrations were made to determine the PT diffusivity. The results of these independent peak measurements have been summarized on Table 21 and Figure 21. A frequency distribution of the apparent diffusivity as determined from the paired odor and tracer measurements has been compared with the independent peak tracer $K'(Y)^{1/2}$ measurements on Figure 22. The distributions do not coincide because the tracer concentration sampled with the odor measurements does not generally represent the peak tracer concentration. This could have occurred because the tracer and source odor locations did not exactly coincide. The net result of this phenomenon is that the apparent site odor emission rate was artifically high. To obtain an adjusted total site odor emission the ratios of the apparent diffusivity of the paired measurements relative to the diffusivity of the peak tracer measurements for the 10th, 50th, and 90th percentile values were multiplied times the apparent odor emission rates at the corresponding percentiles, respectively. The resulting frequency distribution of the adjusted total site odor emissions is presented on Figure 23. The median level of December odor emissions for the BKK site was approximately 48×10^6 ou/min.

Because of changes in site conditions it was not possible to measure the site odor emission rate for January as was done above. Comparisons were made to the "equivalent" site odor emission reduction. The equivalent reduction includes both the effect of site odor emission reductions and changes in micrometeorology. In December there were measurable odors on an average of 72% of responses to complaints with a median downwind odor concentration of 6 ou/cf. A total of 156 complaints were filed during December during the EUTEK evaluation.

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TABLE 21

PEAK TRACER CONCENTRATIONS FROM CROSSWIND TRAVERSES

Date	Time	Measurement Location	Peak (SF_6) (ppb)	x (ft)	$K^1(Y)^{1/2}$ ($ft^{5/2}$/min)	u (mph)	Θ (°N)	ΔT (°F)	T (°F)	RH (%)	Tracer Location
12/4	19:06	End of Lorraine	0.25	2100	4.78×10^5	---	---	-0.1	---	---	K-12
12/5	22:00	Myra & Nogales	4.6	1550	3.02×10^4	2.0	67	0.2	54	75	K-12
12/8	21:43	Amar @ Ridgewood	0.38	3750	2.35×10^5	1.0	175	0.7	50	64	M-12
12/10	18:12	Mary Ct. @ Marlena	4.5	1000	3.85×10^4	0.00	27	---	58	46	N-15
12/11	17:37	200' E. of Mary Ct. on Marlena	4.4	1000	3.93×10^4	0.00	279	---	---	---	N-15
12/11	21:42	200 ft. E. of Mary Ct. on Marlena	3.0	1000	5.77×10^4	0.00	27	---	---	---	N-15
12/12	20:36	100 ft. E. of Mary Ct. on Marlena	0.50	1800	2.58×10^5	1.0	55	---	56	50	J-12
12/15	21:40	Azuaz @ Amar	0.24	4400	2.22×10^5	3.0	85	---	65	44	F-13
12/17	21:45	Amar @ Nogales	0.054	2100	1.43×10^6	0.0	C	---	50	84	F-15
12/19	21:46	200' S. of BKK Entrance on Azusa	1.39	3700	4.2×10^4	5.0	70	---	60	48	O-14
1/5	20:46	200' N. of Azusa & Amar	0.22	6200	2.04×10^5	2.5	45	---	64	23	M-3
1/6	18:45	Miranda 200' E. of Marcella	0.085	1200	1.2×10^6	0.0	C	2.0	60	28	M-12
1/6	22:35	Azusa 100' S. of Carls Jr.	0.14	5500	3.40×10^5	5.0	35	0.0	61	23	M-12
1/7	21:20	100' N. of Carls Jr. on Azusa	0.16	5400	3.00×10^5	0.0	C	0.0	48	81	M-12
1/8	18:50	Amar @ Ridgewood	0.12	4000	4.65×10^5	0.0	C	1.0	52	68	M-12
1/8	21:44	Amar @ Temple	1.6	4500	3.3×10^4	1.5	40	.5	49	78	M-12
1/8	18:39	Azusa @ Jack in the Box	0.62	5500	7.6×10^4	0.0	C	1.0	53	68	M-12
1/8	21:53	Azusa @ Carls Jr.	0.56	5400	8.6×10^4	1.5	40	.5	50	72	M-12
1/9	20:42	Amar @ Woodgate	0.30	3500	1.99×10^5	1.5	270	3.0	---	---	I-17
1/12	21:08	200' N. of BKK on Azusa	0.34	5800	1.36×10^5	5.0	55	.4	---	---	O-11
1/12	22:00	100' W. of Shadow Oak on Amar	1.32	3700	4.4×10^4	2.5	18	.2	---	---	O-11
1/13	20:15	Miranda (mid-street)	0.40	1000	2.8×10^5	0.0	C	0.5	49	87	O-11
1/13	20:27	Amar @ Woodgate	3.4	2000	2.3×10^4	0.0	C	0.5	53	84	O-11
1/14	20:00	Marlena @ Nogales	1.1	1700	7.8×10^4	0.0	C	1.0	53	84	O-11

Note: Q = 155 cc/min 12/4 to 12/12, Q = 100 cc/min 12/15 - 1/14.

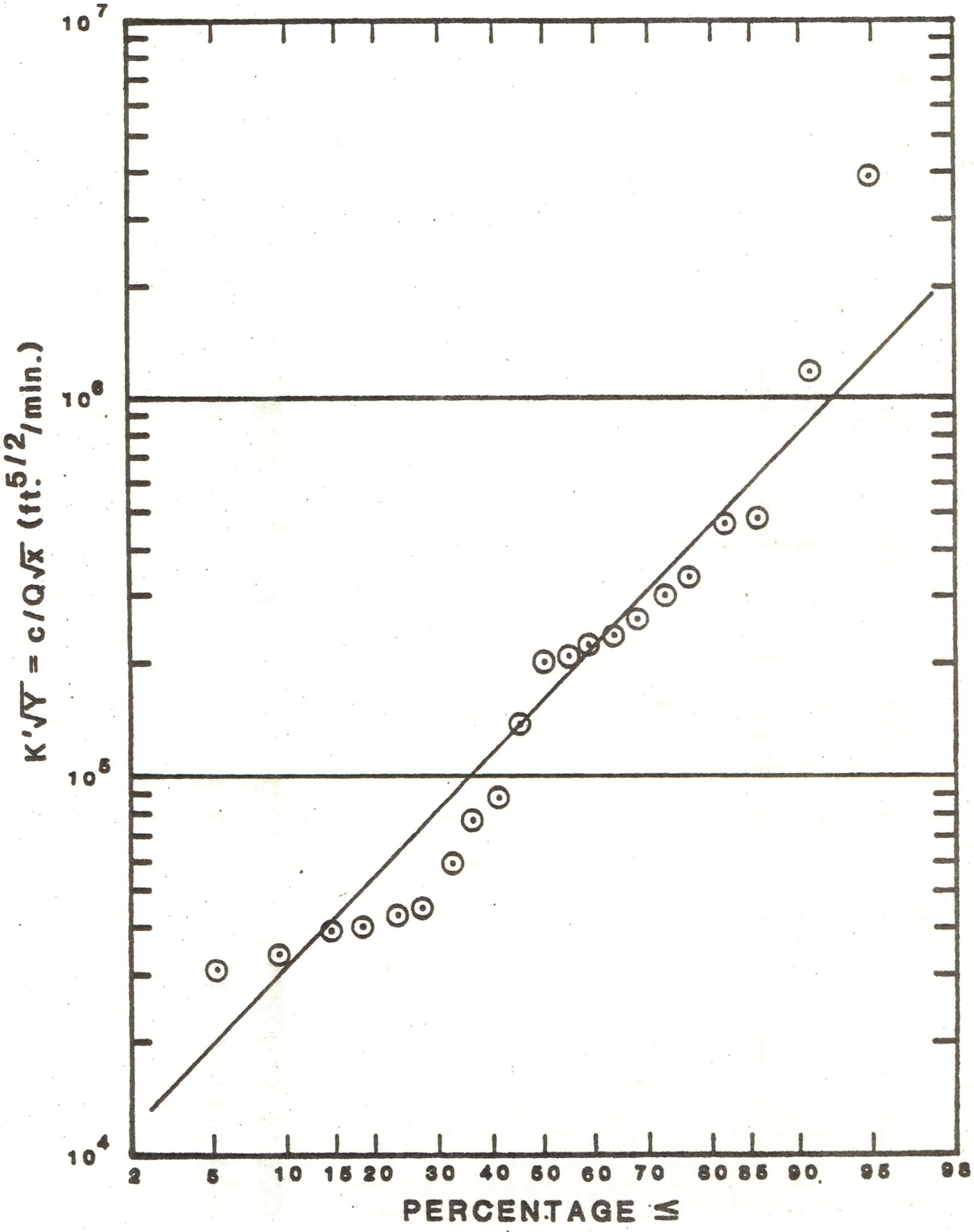

FIG. 21 FREQUENCY DISTRIBUTION OF PEAK TRACER $K'\sqrt{Y}$

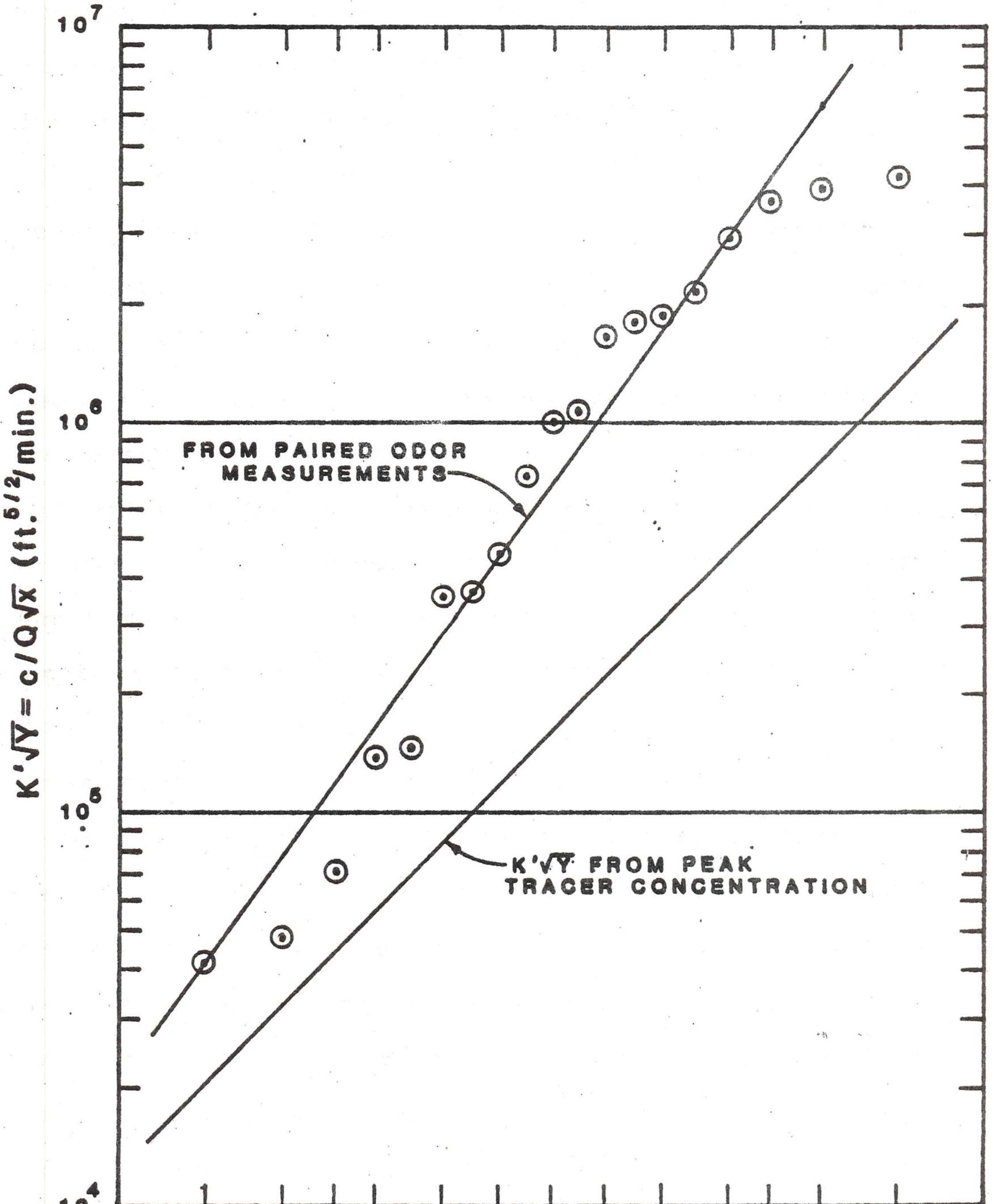

FIG. 22 $K'\sqrt{Y}$ FROM PAIRED ODOR MEASUREMENTS vs $K'\sqrt{Y}$ FROM PEAK TRACER CONCENTRATION

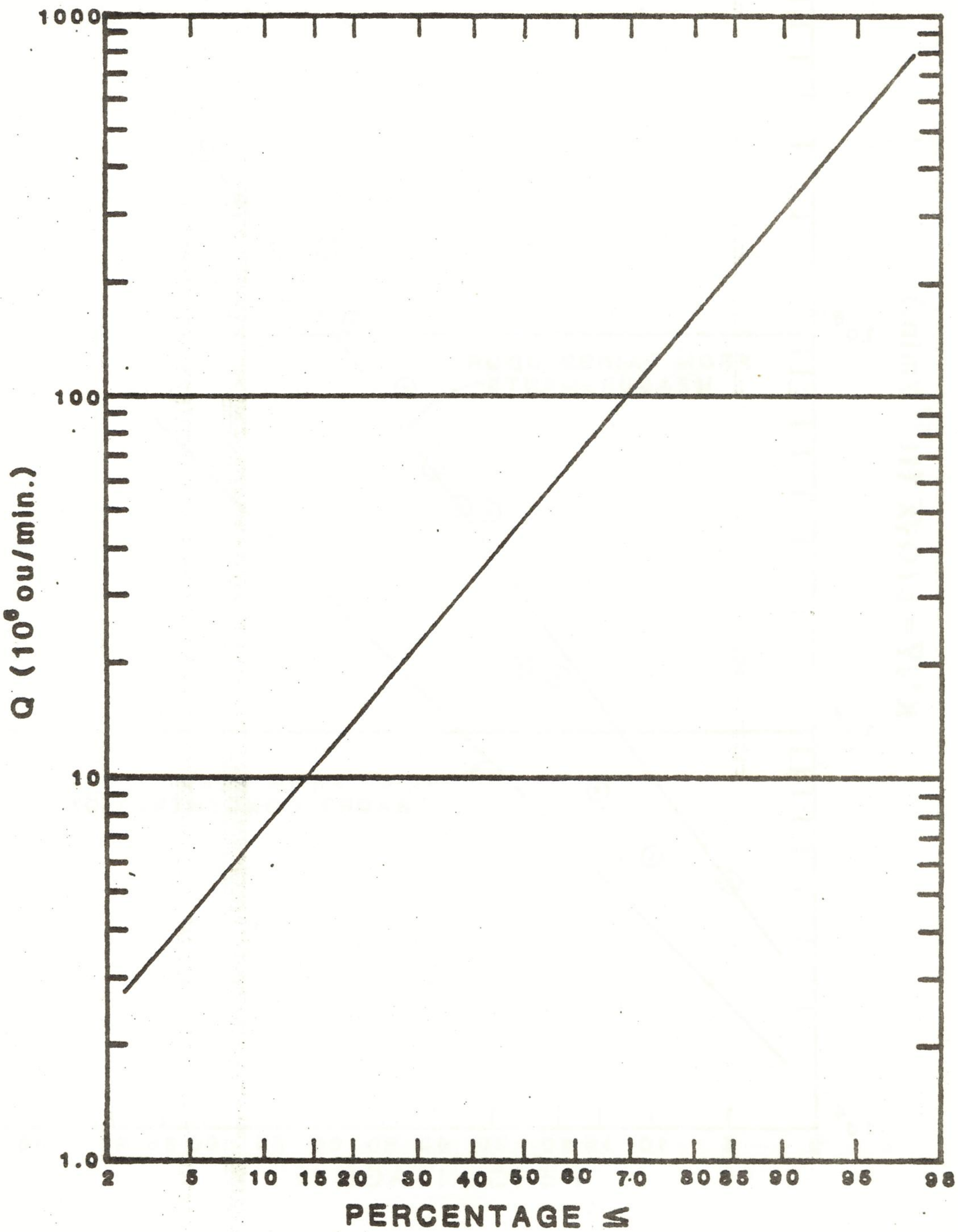

FIG. 23 ADJUSTED FREQUENCY DISTRIBUTION OF TOTAL SITE ODOR EMISSIONS (Q)

In contrast, January yielded measurable odors on an average of 36% of responses to complaints with a median downwind odor concentration of 6 ou/cf. A total of 85 complaints were filed during January during the EUTEK evaluation. Thus, the "equivalent" reduction in site odor emissions in January relative to December would be:

$$\frac{Q_{Jan}}{Q_{Dec}} = \frac{(\text{\% Positive Responses})(\text{ou/cf})(\text{complaints})_{Jan}}{(\text{\% Positive Responses})(\text{ou/cf})(\text{complaints})_{Dec}}$$

$$= \frac{(.36)\,(6)\,(85)}{(.72)\,(6)\,(156)}$$

$$= 0.27$$

Thus, approximately, the apparent equivalent site odor emission % reduction would be,

$$\text{Apparent Reduction in Q (\%)} = 1 - \frac{Q_{Jan}}{Q_{Dec}} \times 100$$

$$= 73\%$$

PROBABLE SOURCES OF LANDFILL ODORS

The generic source of odors from the BKK Class I Landfill are solid and liquid wastes which have been placed in the landfill since the start of its operations in 1962. Solid and liquid wastes are hauled to the landfill on a daily basis and are placed and compacted in a relatively small area termed the working face. This working face is exposed to the open air between approximately 6 a.m. and 6 p.m. A 6 to 12 inch vertical compacted soil cover is placed over the working face at the end of each day. The working face is typically covered by approximately 6 p.m. each day. Thus, the solid and liquid waste in the working face are exposed to the air for a maximum of 12 hours each day.

The procedures employed at the BKK Landfill are in accord with industry standards. Inspection officers from the State Solid Wastes Management Board have reported that the BKK site is operated in an exemplary manner (5).

Solid and liquid waste begin decomposition immediately through microbiological activity. The rate of decomposition depends on the organic and moisture content of the waste. Decomposition occurs initially aerobically (with oxygen). Once oxygen is depleted decomposition will occur anaerobically. Decomposition of the waste produces gases including carbon dioxide, methane, and other decomposition products. The gas produced by the decomposing solid and liquid waste is sufficient to develop a positive static pressure relative to atmospheric pressure. The differential pressure forces the migration of the gas along the path of least resistance through the soil to the atmosphere. Landfill gas will escape most readily through settlement cracks and fissures of the earth cover of the waste. Any point within the landfill which allows the escape of gas is a source of odors.

The positive gas pressure within a landfill can be relieved to some extent through placement of gas recovery wells within the landfill and evacuating gas from these wells utilizing a centrifugal blower. The wells are maintained at a slightly negative pressure relative to atmospheric pressure. Migrating landfill gases are preferentially carried to the wells due to the greater pressure differential.

The recovered gas is normally "flared" by mixing it with air and combusting the mixture. If the temperature of combustion is high enough, odorants in the gas are thoroughly oxidized to odorless products. Incomplete combustion will occur at lower temperatures resulting in partial oxidation of odorants. Under these circumstances odors can occur from the gas recovery burners.

To prevent a gas recovery system from becoming a major source of odors, certain conditions must be met. Measures should be taken while gas wells are being drilled to prevent the escape of gas to the atmosphere. Alarm systems should be installed and operated to notify personnel immediately of breaks in pipelines or of inadequate combustion conditions.

Measurements were completed in order to determine the nature and potential significance of the working face, gas migration, and gas recovery system in producing detectable odors downwind of the BKK Landfill. Surface odor emission rate (SOER) measurements were completed at several locations within the Landfill. Results of these measurements are presented on Table 22. Unit area SOER varied from 4 to 3500 ou/min/sf. The unit area SOER varied in one case by a factor of 50 within a distance of only 15 ft. The strength of the unit area SOER was dependent upon the presence or absence of surface fissures or cracks. Where cracks were present, very high readings were obtained. If the surface cover was fresh and contained no direct escape routes for gas, readings were relatively low. The results of the SOER measurements indicate the spotty nature of odor emissions from the landfill. It would appear that a number of "hotspots" occur at various locations throughout the landfill, however, at any one "hotspot" location the SOER varies with time. These "hotspot" locations change continually as new wastes are deposited in the landfill and as grooming and landfill placement occurs.

Several ambient odor measurements were completed within the landfill in order to determine the effect of the working face on ambient odors. The results of the landfill ambient odor measurements are presented on Table 23. The highest ambient odor concentration within the landfill was measured on the working face. The working face had an odor concentration of 15 ou/cf. This was not significantly higher than concentration of odors measured in downwind neighborhoods. There was infrequent occurrence of detectable working face odors during evening hours due to placement of the final earth cover at the end of each day.

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TABLE 22

SURFACE ODOR EMISSION RATE MEASUREMENTS

Date	Time	Location	SOER (ou/min/sf)	Comments
12/19	16:30	Upper deck - South Slope	3500	Gas
12/19	16:35	Upper deck - South Slope	70	15' from 16:30 measurement
12/19	16:50	East Terraces	70	Over surface crack
12/19	16:55	East Terraces	35	Over surface crack
12/19	17:00	East Terraces	10	-----
12/19	17:05	East Terraces	210	-----
12/19	17:25	Winter Dump Area on Road	4	-----
12/19	17:30	Winter Dump Area on Road	4	-----

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TABLE 23

LANDFILL AMBIENT ODOR MEASUREMENTS

Date	Time	Location	Odor (ou/cf)	u (mph)	θ (°N)	T (°F)	ΔT (°F)	RH (%)	Comments
12/9	16:35	South finished slope	10	0	calm	57	3.0	45	Garbage mint odor
12/9	17:00	Working face	15	0	calm	58	1.6	52	Closing face
12/9	17:15	Near gas burners	10	0	calm	57	1.6	53	-----
12/9	17:30	Top deck @ WS-3	3	2	270	52	1.1	53	-----
12/10	16:15	South finished slope	2	4-6	NW	70	—	33	Garbage
12/10	16:40	Top deck @ WS-3	6	4	W/NW	68	—	40	-----
12/10	16:50	Working face	8	5-7	NW	65	—	41	Mint/garbage
12/10	17:00	Near gas burners	8	0	calm	66	—	42	Garbage/gas

Landfill gas within the gas recovery system can be a major source of odors. As indicated on Table 24, unburned landfill gas had odor concentrations of between 100,000 and 500,000 ou/cf. After mixing with air and combustion, the exhaust odor concentrations ranged from 75 to 150 ou/cf. The gas burner exhaust constituted a minor source of odor relative to the potential odor of migrating raw landfill gas with odor concentrations ranging from 100,000 to 500,000 ou/cf.

The composition of recovered landfill gas was determined. The results have been summarized on Table 25. The high odor concentration is accounted for by a complex mixture of odorants including hydrogen sulfide, dimethyl sulfide, diethyl sulfide, chlorinated hydrocarbons, and over 15 other low molecular weight hydrocarbons. Reduced sulfur compounds appear to be primarily responsible for the high odor concentration due to their low odor thresholds. Other hydrocarbons present are odorous but they do not account for much odor because of significantly higher thresholds.

Two separate samples of landfill gas were analyzed. Although the composition of their major components (CH_4, CO_2, N_2 and O_2) were similar, the composition of the minor components showed an order of magnitude difference. Part of this difference could be due to sampling techniques. Although most compounds showed up in both samples there were a number of compounds unique to a sample. There may be significant time and space variation in the gas composition and thus significant changes in the gas odor concentration The high nitrogen content of the landfill gas indicated that significant air leakage occurred in the gas collection system. Methane content is usually approximately 40% with nitrogen accounting for less than 20%.

Samples of displaced air from the Cyanide and Nitric HF disposal wells were analyzed to determine their composition. Far fewer compounds were found than were found in the landfill gas (Table 25). Several compounds not appearing in the

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TABLE 24

GAS BURNER ODOR REDUCTION EFFICIENCY

		Odor Concentration (ou/cf)		H_2S Concentration (ppm)	
Date	Time	Landfill Gas	Gas Burner Exhaust	Landfill Gas	Gas Burner Exhaust
12/10	---	---	75	---	---
12/11	22:35	---	150	---	---
12/15	22:45	---	100	---	---
12/16	22:00	---	100	---	0
12/17	22:00	500,000	---	10	---
12/19	18:30	100,000	100	---	---

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TABLE 25

GC ANALYSIS OF GAS SAMPLES
(ppm unless noted)

Compound	Surface Sample	Nitric Well	Cyanide Well	Landfill Gas Sample 6	Landfill Gas Sample 3	Burner Exhaust
methane				18.6%	20.0%	
carbon dioxide				20.9%	21.9%	
nitrogen				48.2%	45.2%	
oxygen				9.6%	9.4%	
argon				0.5%	0.5%	
other hydrocarbons				2.2%	1.2%	
chloroethene	140			1200	100	
chloroethane				250	10	
dichloromethane	1200			1500	50	
dimethyl sulfide[a]				400	---	
2-proponal				250	20	
1-1 dichloroethene				1200	100	
1-1 dichloroethane	100	20		5000	500	
1-2 dichloroethene	70			800	50	
1-2 dichloroethane	500	50	20	5000	500	20
2-butanol	---			250	10	
cyclohexane	---			250	20	
methylcyclopentane	60			500	40	
2-3 dimethylbutane				500	30	
trichloroethene	80	20		1000	50	
benzene	120	20	10	2000	150	
hexane	80			500	250	
1-3 dimethyltranscyclopentane	90			750	---	
diethylsulfide				250	---	
methylethylsulfide				50	---	
methylcyclohexane	170	10		1250	100	
2-2 dimethylpentane				500	30	
2-3 dimethylpentane	80			750	---	
C_8H_{16}	100			750	---	
tetracholorethene		10		1500	100	
toluene	500	40	20	3500	300	10
1-2-3 trimethylcyclohexane				500	---	
chlorobenzene				500	40	
2-5- dimethylhexane				500	---	
4-ethyl 2 methylhexane				500	---	
octane				500	---	
1-1 trichloroethane		150				
1,1,2 trichloroethane		10	10			3
methyl sulfide				---	10	
1,2 dimethylcyclopentane				---	40	
2,2,3 trimethylhexane				---	40	
unsat. hydrocarbon				---	50	
C_9H_{20}				---	10	
2-4 dimethylhexane				---	30	
2 propanone	100					
2 methylbutane	50					
2,2,3,3, tetramethylbutane	100					
dibutylesterethanedioicacid						
4 methyl 1 hexanol		10				
3,5,5 trimethyl, 1 hexene		0.5				
1,1,1, trichloroethane			30			10
1,1 dimethylcyclopentane			10			
Total reduced sulfur as H_2S	40.3	165	255	134	71.5	298

[a]Includes mercaptans, if present

landfill gas samples appeared in the disposal well displaced air sample. The trace composition of many compounds in the landfill gas was apparently influénced by the composition of liquid and solid wastes disposed at the site of gas generation.

Samples of exhaust from the gas recovery burners were also analyzed (Table 25). Only four trace gases were found. The concentrations were significantly lower than those found in the raw gas. The combustion efficiency appeared to be very good with the exception of total reduced sulfur compounds. The reason for the finding of high reduced sulfur compounds in the exhaust has not been explained.

The final gas analysis was completed on a sample of air obtained by isolating an odorous "hot spot" on the landfill surface with a hood. Soil filtration apparently reduced the total number of compounds but some compounds were not significantly affected by soil filtration. The soil was effective in removing reduced sulfur compounds. Elimination of reduced sulfur compounds would be consistent with a reduction in odor concentrations.

The landfill SOER measurements (Table 22) indicated that significant odor reduction occurs as the gas migrates through the soil. The BKK Corporation estimated that approximately 6,600 cfm of landfill gas was continuously generated during the study period. The gas recovery system had a capacity to recover 2,200 cfm. Thus, approximately 4,400 cfm of the gas was migrating through the soil cover of the landfill.

Gas that escapes the gas recovery system either through migration along the gas wells or gas pipelines passes into the atmosphere without benefit of soil filtration and thus can constitute a major source of odors. On at least one occasion during the study, equipment at the landfill broke a gas line which allowed the direct venting of landfill gas into the atmosphere. This accident resulted in the highest downwind odor concentrations measured during the study.

In conclusion, under normal operating conditions, it appeared that the migration of gas to the surface of the landfill constituted the major source of detectable downwind odors. The escape of the gas was spotty and highly variable. The location of odor "hotspots" appeared to change very quickly. If a hotspot surface crack was repaired by placement of additional cover the odor concentration was reduced but, presumeably, the gas found a new path of least resistance for escape into the atmosphere.

PRIMARY EXPLANATION FOR ODOR PROBLEMS

The odor problems experienced at the BKK Landfill could result from the combination of a number of different factors including the following:

1. High site odor emission rates.
2. Close proximity of residences.
3. Downslope drainage of cool air during calm conditions.
4. Working face odors.

The working face is typically closed at 6 p.m. and cannot account for the large number of complaints that occurred in the late evening hours. Working face odors may account for some daytime odor complaints however they did not appear to be the major problem.

The remaining three factors, downslope drainage, high site odor emission rates, and close proximity of residences provide the primary explanation for the BKK Landfill odor problems. The BKK Landfill is located uphill from surrounding residences. Homes in the M Street area are located immediately adjacent to finished slopes of the landfill from which gas migration can occur.

Calm conditions prevail on approximately 90% of the evenings. The presence of a nighttime calm condition can result in an inversion because of cooling from below. The relatively cool air near the ground surface drains downslope picking up surface emissions of landfill gas.

The downslope drainage phenomena was documented visually in Plates 19 and 20. A smoke candle was lit on the top deck as shown in Plate 19. The smoke was initially warm but as it cooled it spread out laterally and crept close to the ground. The smoke continued to move across the flat portion of the top deck and on down the slope as shown in Plate 20. The smoke was observed to continue moving in a downhill direction despite the calm condition. These extremely stable conditions which were frequently observed to occur at the BKK site prevent the dispersion of collected odors and result in high downwind odor concentrations.

Mitigation measures must be designed to counteract the mechanism which results in the severe downwind odor conditions. Given that downwind distances to residential areas cannot be changed, mitigation must necessarily focus on reductions in site odor emissions and modifications to site micrometeorology and dispersion conditions. Such mitigation measures will be discussed in the sections following.

BARRIER EFFECTIVENESS

The effectiveness of the barriers in reducing downwind odor concentrations was under evaluation since the third week of the study. The barrier evaluation centered on the effectiveness of barriers in modifying dispersion under critical transport conditions with wind speeds greater than 2 mph.

Summary results of the barrier evaluation are presented on Table 26. Barrier effectiveness was evaluated by comparing the ratio of the downwind tracer

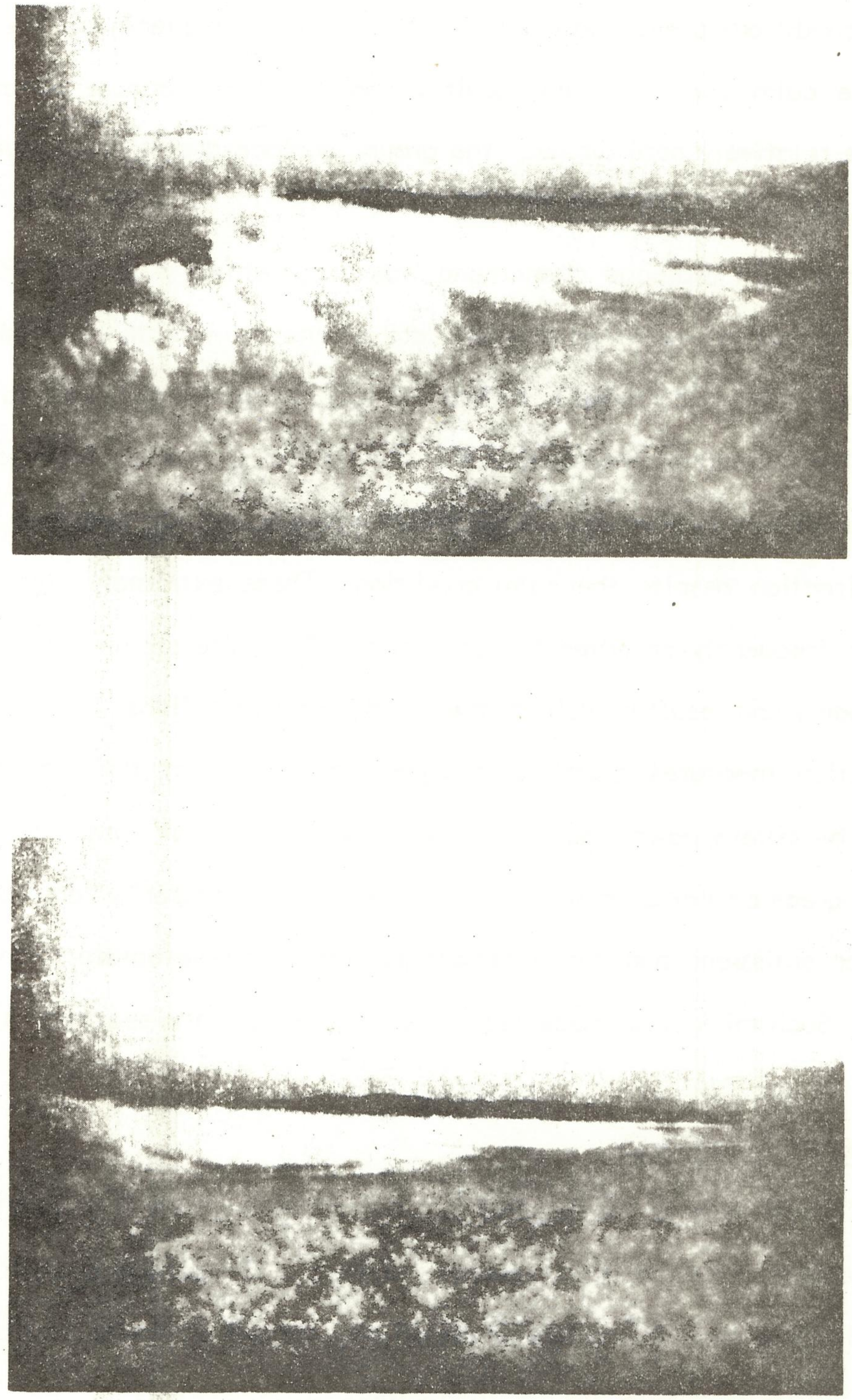
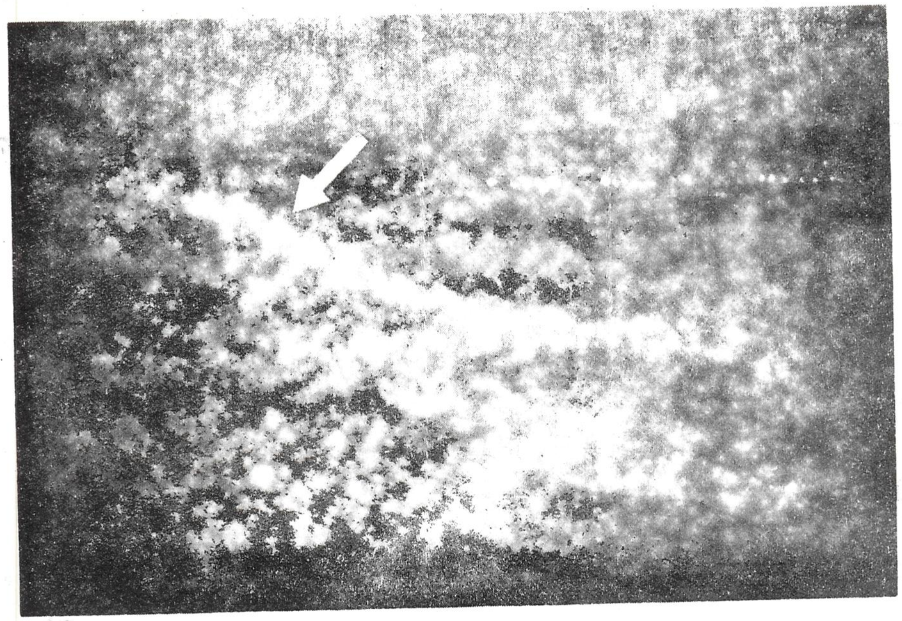


PLATE 19 SMOKE FLOW VISUALIZATION OF DOWNSLOPE COLD AIR DRAINAGE, TOP DECK



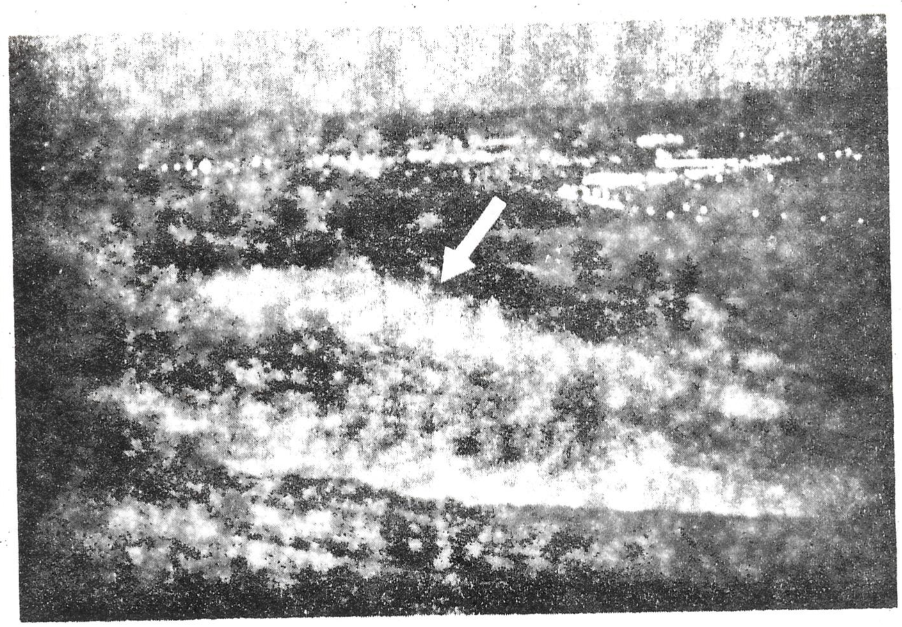


PLATE 20 SMOKE STUDY OF DOWNSLOPE DRAINAGE OF COLD AIR

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TABLE 26

SUMMARY RESULTS - BARRIER EFFECTIVENESS

Date	Time	(SF_6) c_1 @ Lynn Ct. (ppb)	(SF_6) c_2 @ WS-2 (ppb)	C_1/C_2	ΔT (°F)	u (mph)	Θ (°N)	Temp WS-2 (°F)	RH (%)	Tracer Location
12/8	21:30	0.19	0.06	3.17*	0.7	1.0	175	52	63	M-12
12/9	21:23	0.042	0.042	1.0*	1.6	0.00	315	49	71	M-3
12/9	21:24	0.044	0.029	1.52*	1.6	0.00	315	49	71	M-3
12/10	20:25	0.75	0.40	1.88*	---	2.5	97	61	43	N-15
12/10	20:30	0.13	0.36	0.36*	---	2.5	97	60	43	N-15
12/10	22:12	0.22	0.35	0.63*	---	1.5	75	52	39	N-15
12/12	20:30	0.13	0.10	1.30	---	1.0	48	54	49	J-12
12/12	21:40	0.56	0.03	1.87	---	4.0	60	55	54	J-12
12/15	20:04	0.52	1.5	0.35	---	0.0	calm	62	45	F-13
12/15	20:13	0.52	0.58	0.90	---	0.0	calm	62	45	F-13
12/15	20:55	1.5	0.4	3.75	---	0.0	calm	63	45	F-13
12/15	21:00	0.8	0.8	1.0	---	0.0	calm	63	45	F-13
12/15	21:05	0.4	0.58	0.69	---	0.0	calm	63	45	F-13
12/15	21:10	0.36	0.28	1.29	---	0.0	calm	62	45	F-13
12/15	21:15	0.15	0.25	0.60	---	0.0	calm	62	45	F-13
12/15	21:20	0.09	0.18	0.50	---	0.0	calm	62	45	F-13
12/15	21:50	0.18	0.20	0.90	---	1	330	64	42	F-13
12/15	22:25	0.08	0.044	1.82	---	0.5	330	66	42	I-17
12/15	22:35	0.021	0.02	1.0	---	0.0	calm	67	42	I-17
12/16	20:05	0.025	0.44	0.06	---	0.5	75	66	52	F-15
12/16	20:20	0.41	1.2	0.34	---	0.5	60	65	50	F-15
12/16	20:25	0.46	1.0	0.46	---	0.5	60	65	49	F-15
12/16	20:30	0.62	1.4	0.44	---	0.5	60	65	49	F-15
12/16	20:35	0.49	0.3	1.63	---	0.0	calm	65	49	F-15
12/16	20:40	1.3	1.0	1.30	---	0.5	60	64	49	F-15
12/16	20:45	0.6	0.19	3.16	---	0.0	calm	64	50	F-15
12/16	20:50	0.8	0.50	1.60	---	0.5	60	64	50	F-15
12/17	17:05	0.13	0.25	0.52	---	0.0	calm	60	58	F-15
12/17	17:10	0.58	0.14	4.14	---	0.0	calm	60	60	F-15
12/17	18:25	0.22	0.024	9.17	---	0.0	calm	58	69	F-15
12/17	18:35	0.025	0.06	0.42	---	0.5	40	57	71	F-15
12/17	18:55	0.048	0.06	0.80	---	0.5	40	54	75	F-15
12/17	19:00	0.09	0.06	1.50	---	0.5	40	54	76	F-15
12/17	21:00	0.03	0.10	0.30	---	0.0	calm	51	83	F-15
12/17	21:05	0.077	0.13	0.59	---	0.0	calm	51	83	F-15
12/17	21:15	0.02	0.070	0.29	---	0.5	40	50	84	F-15
12/17	21:25	0.02	0.036	0.56	---	0.0	calm	50	86	F-15
12/18	21:35	0.52	0.18	2.89	---	0.0	calm	47	83	G-16
12/18	21:40	0.50	0.32	1.56	---	0.0	calm	47	83	G-16
12/18	21:45	1.05	0.63	1.67	---	0.0	calm	47	82	G-16
12/18	21:50	0.67	0.49	1.37	---	0.0	calm	47	82	G-16
1/9	20:20	1.1	0.04	27.5	2.0	0.0	270	---	---	I-17
1/9	20:25	.11	0.08	1.37	2.0	0.0	270	---	---	I-17
1/9	20:35	.022	0.07	.31	3.0	4.0	30	---	---	I-17
1/9	20:55	0.4	0.2	2.0	3.0	1.0	33	---	---	I-17
1/9	21:00	0.9	0.06	15.0	2.0	0.0	300	---	---	I-17
1/9	21:05	0.038	0.1	.38	2.0	3.0	10	---	---	I-17

*Prebarrier condition

concentration (c_1) to the upwind tracer concentration (c_2) before and after construction of the barrier. If the ratio c_1/c_2 is less than or equal to one, the reduction in tracer concentration could be attributed in part to the presence of the barrier. Conversely if c_1/c_2 was greater than or equal to one, the barriers would not have been effective in reducing downwind concentrations. A frequency distribution showing c_1/c_2 for pre-barrier and post-barrier conditions is presented on Figure 24. For both pre- and post-barrier conditions the ratio of c_1/c_2 was less than one only approximately 50% of the time. The pre- and post-barrier conditions appeared to be nearly identical indicating that the barrier was not effective under the frequently calm evaluation conditions.

In large part the micrometeorological conditions prevailing at the BKK site during the evaluation explain the lack of barrier mixing. Ninety percent of the measurements were made under conditions of wind speeds less than 2 mph thereby obviating the possibility of barrier mixing due to eddy generation. Approximately 60% of the measurements were made with RH less than 50% under strong inversion conditions. Mixing such stable air would be extremely difficult even with mechanical assistance (wind machines). Smoke visualization studies conducted at the West Window confirmed the tracer results.

The barrier was found to act as a cold air dam. Temperature gradient measurements were made both upwind and downwind of the barrier to determine their effect on cold air movement. Figure 25 shows a profile of temperatures measured approximately 2 feet on either side of the barrier at the noted elevations. <u>The difference in upwind and downwind temperature on the barrier was as much as 9°F.</u> Cold air was essentially trapped on the landfill side of the barrier. Any downslope drainage air from the landfill which was warmer than this air trapped behind the barrier would tend to move over the top of the barrier without intermixing with the relatively cold stable air trapped behind the barrier.

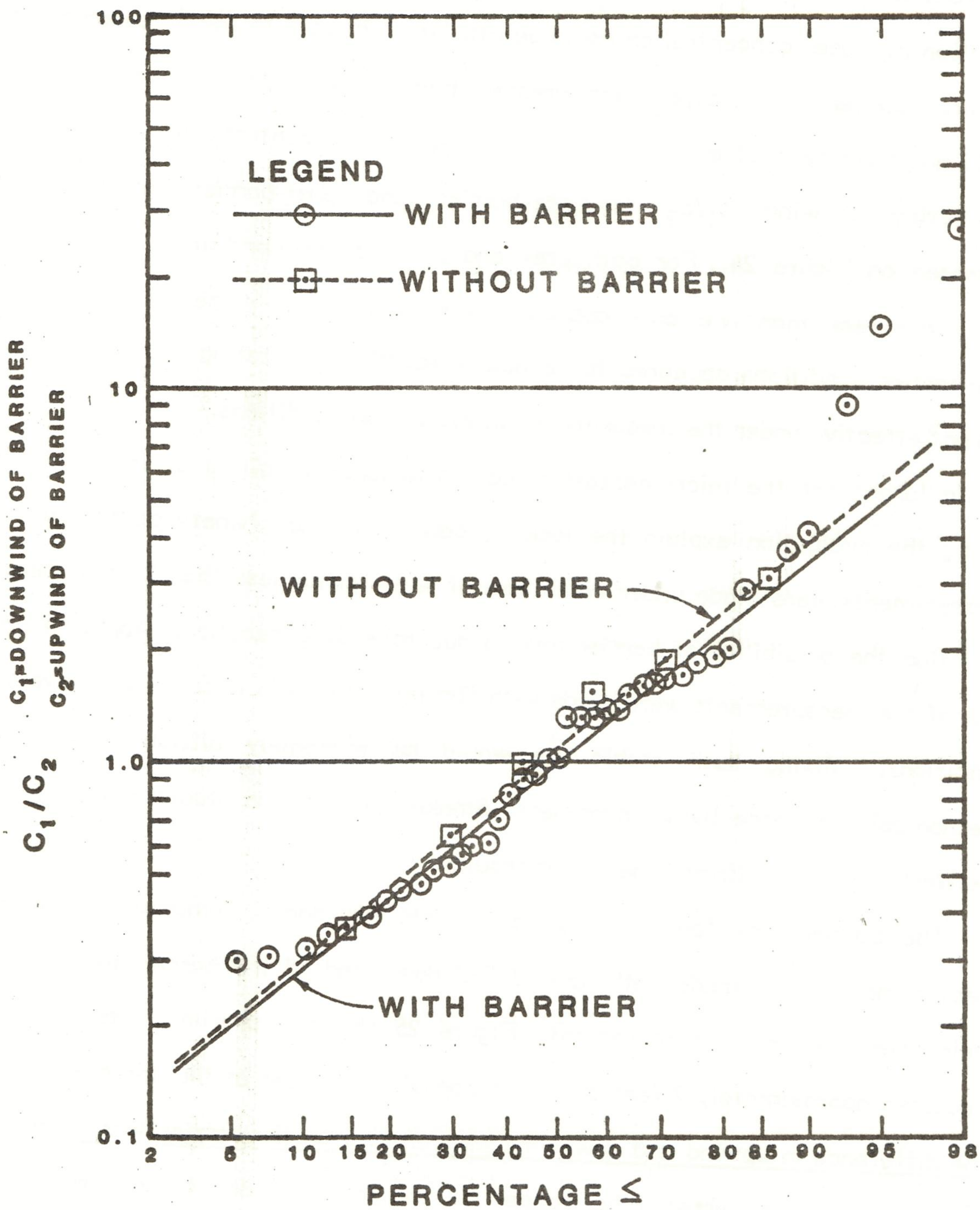

FIG. 24 C_1/C_2 FOR PRE AND POST BARRIER INSTALLATION

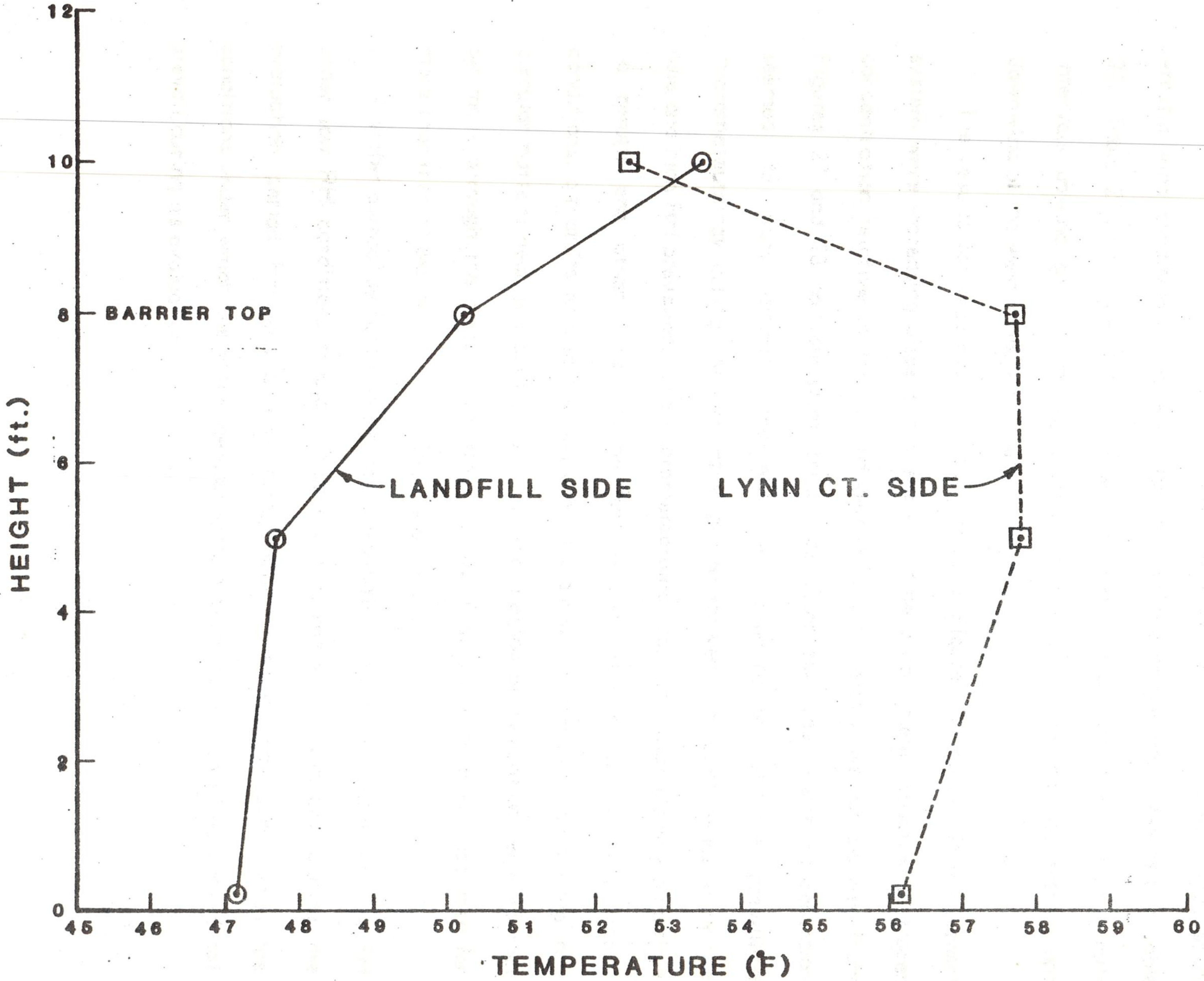

FIG. 25 TYPICAL BARRIER TEMPERATURE PROFILE

Temperature measurements at various elevations within the landfill confirmed that the air was generally warmer at higher elevations. The presence of cold air traps was also confirmed. A typical landfill temperature traverse is presented on Figure 26.

The ability of the barriers to dam and provide channeling of cold air may ultimately prove to be useful at the BKK site. Barriers could be used with earthen levees to redirect downslope cold air drainage away from nearby residences. The design criteria for such a system should be field evaluated.

In conclusion, barriers were not effective in increasing dispersion under the conditions evaluated. Under the prevailing calm conditions the barrier acted as a cold air dam. Warmer air moved over the cold air without significant intermixing. Barriers have been shown to be effective mixers when wind speeds in excess of 2 mph prevail. Barriers may prove to be effective mixers at the BKK site during other times of the year. Under calm conditions, barriers would have to be used in conjunction with wind machines to induce mixing.

WATER AEROSOL EFFECTIVENESS

The effectiveness and potential of a water aerosol system for mitigating downwind odors was evaluated during the last two weeks of the baseline data collection period. The water aerosal system was designed to increase RH in the air. Increased RH can result in fewer and less severe ground level temperature inversions. If inversion strength is reduced, the frequency of high magnitude downwind odor concentrations would be reduced.

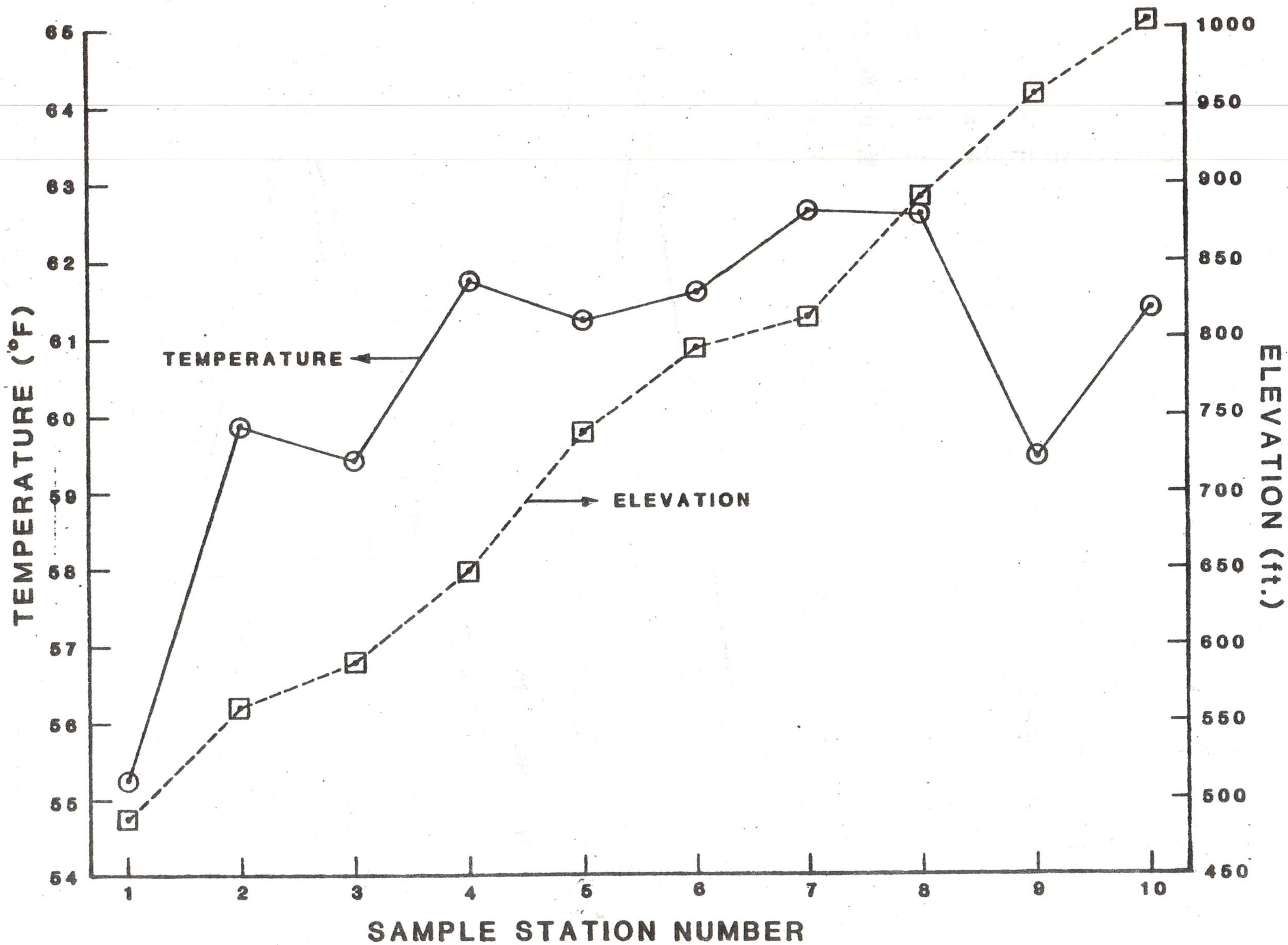

FIG. 26 TYPICAL TEMPERATURE TRAVERSE

The aerosol system was evaluated using a tracer study, smoke flow visualization and measurements of RH. Tracer results proved difficult to obtain because of erratic wind conditions. Those results that were obtained are presented in Table 27. Table 27 shows the results of simultaneous tracer sampling at five minute intervals upwind of the aerosol system, downwind of the aerosol system and downwind of the west window barrier.

The results for 1/20 and 1/21 are plotted in Figures 27 and 28. If the aerosol system were increasing dispersion there should be a consistent reduction in tracer concentration relative to the upwind aerosol concentration. As can be seen from Figures 27 and 28 no consistent trend was observed. The tracer concentraion seemed to vary almost randomly. An examination of the prevailing micrometeorology during the evaluation period showed that calm winds were the rule and high RH prevailed. The micrometeorology certainly explains why sometime no results and other times inconsistent results were obtained. Under calm conditions, air drifts erratically. On one day, air was observed to be moving in a circular pattern near the aerosol system. The method of evaluation required that air move through the aerosol in a steady flow. That condition never occurred for more than a short period of time during the evaluation.

A water aerosol system is designed for conditions of low RH. Increasing the RH under low RH conditions should mitigate the strength of inversion. During the evaluation period RH was already high, usually greater than 80%. Thus the conditions under which the water aerosol system could have been effective did not prevail during its evaluation.

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TABLE 27

WATER AEROSOL SYSTEM EVALUATION

Date	Time	(SF_6) c_1 @ @ Lynn Ct. (ppb)	(SF_6) c_2 @ @ WS-2 (ppb)	(SF_6) c_3 @ upwind (ppb)	Q[a] (cc/min)	c_1/c_2	c_2/c_3	ΔT (°F)	u (mph)	Θ (°N)	Net Radiation (watts/m^2/sec)	Temp (°F)	RH Upwind of aerosol (%)	RH Downwind of aerosol (%)
1/19/81	21:10	---	0	0	100	---	---	---	calm	calm		50		90
	21:15	---	0	0.28	100	---	---	---	calm	calm		50		90
	21:20	---	0	0	100	---	---	---	calm	calm		50	85	90
	21:25	---	0	0	100	---	---	---	calm	calm		50		95
	21:30	---	0	0	100	---	---	---	calm	calm		50		95
	21:35	---	0	0	100	---	---	---	calm	calm		50		95
1/20/81	20:25	0.85	0.8	0.87	100	1.06	0.92	0.5	calm	calm	-97	52		100
	20:30	0.80	0.95	0.70	100	0.84	1.36	0.5	calm	calm	-97	52		100
	20:35	2.3	2.5	0.75	100	0.92	3.33	0.5	calm	calm	-97	52		100
	20:40	1.1	0.15	0.84	100	7.33	0.18	0.5	calm	calm	-97	52	90	100
	20:45	0.25	0.44	0.02	100	0.57	22.0	0.5	calm	calm	-97	52		100
	20:50	0	0	0	100	---	---	0.5	calm	calm	-97	52		100
	20:55	0	0	2.0	100	---	---	0.5	calm	calm	-97	52		100
	21:00	0	0	0	100	---	---	0.5	calm	calm	-97	52		100
	21:05	0	0	0	100	---	---	0.5	calm	calm	-97	52		100
	21:10	0.28	0.65	0.77	100	2.32	0.84	0.5	calm	calm	-97	52		100
1/21/81	18:30	1.05	0.2	0.15	100	5.25	1.33	2.0	calm	calm	-129	56		90
	18:35	0.50	0.17	0.07	100	2.94	2.43	2.0	calm	calm	-129	56		90
	18:40	1.2	0.45	1.4	100	2.67	3.11	2.0	calm	calm	-129	56	80	90
	18:45	0.52	1.0	0.12	100	0.52	8.33	2.0	calm	calm	-129	56	80	90
	18:50	0.85	0.80	0.23	100	1.06	3.48	2.0	calm	calm	-129	56		90
	18:55	1.35	0.79	0.59	100	1.71	1.34	2.0	calm	calm	-129	56		95
	19:00	1.45	0.90	1.2	100	1.61	0.75	2.0	calm	calm	-129	56		95
	19:05	0.56	0.54	0.70	100	1.04	0.77	2.0	calm	calm	-129	56		95

[a] Tracer location was F-15 for all runs.

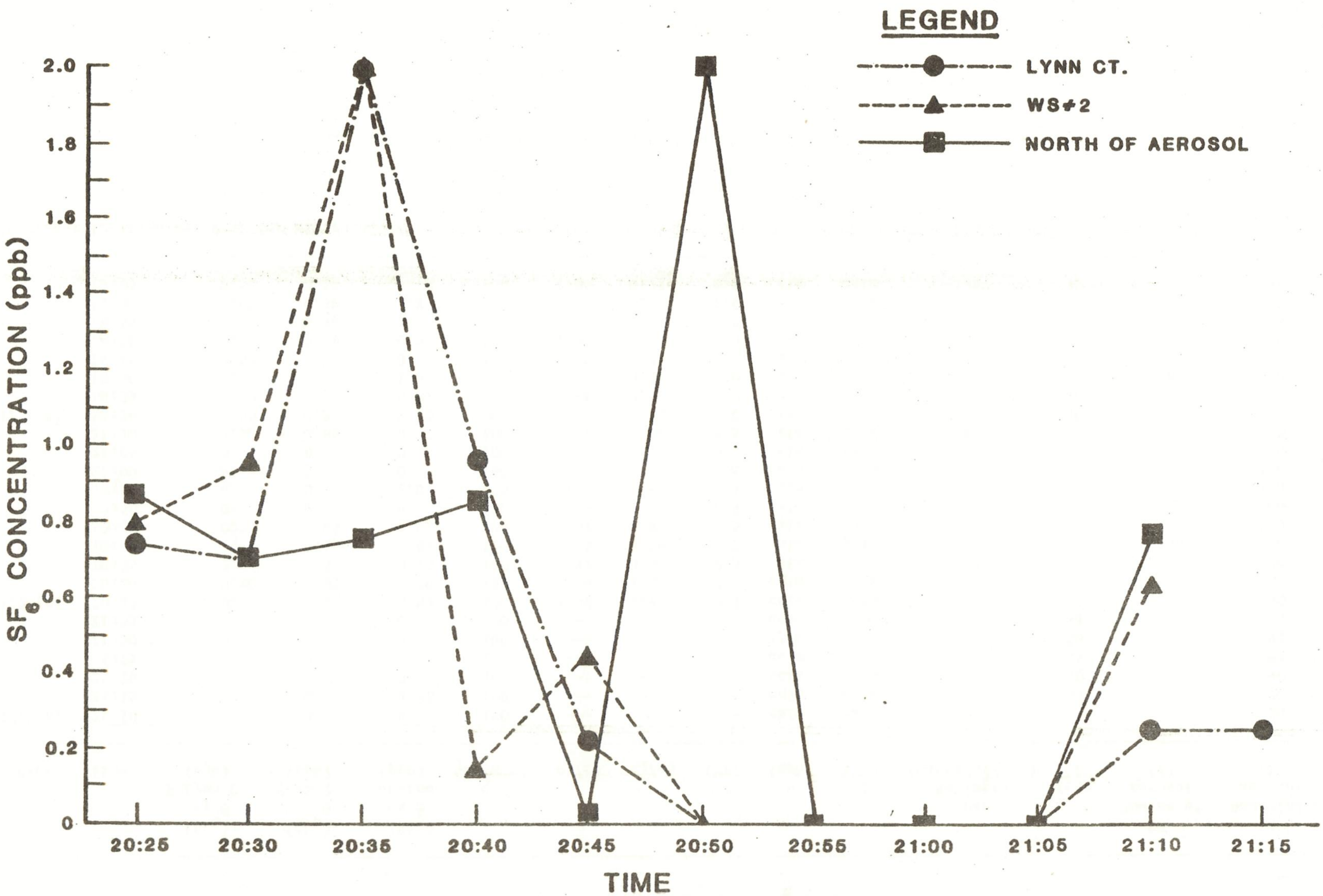

FIG. 27 TRACER CONCENTRATIONS VERSUS TIME FOR WEST WINDOW (1/20/81)

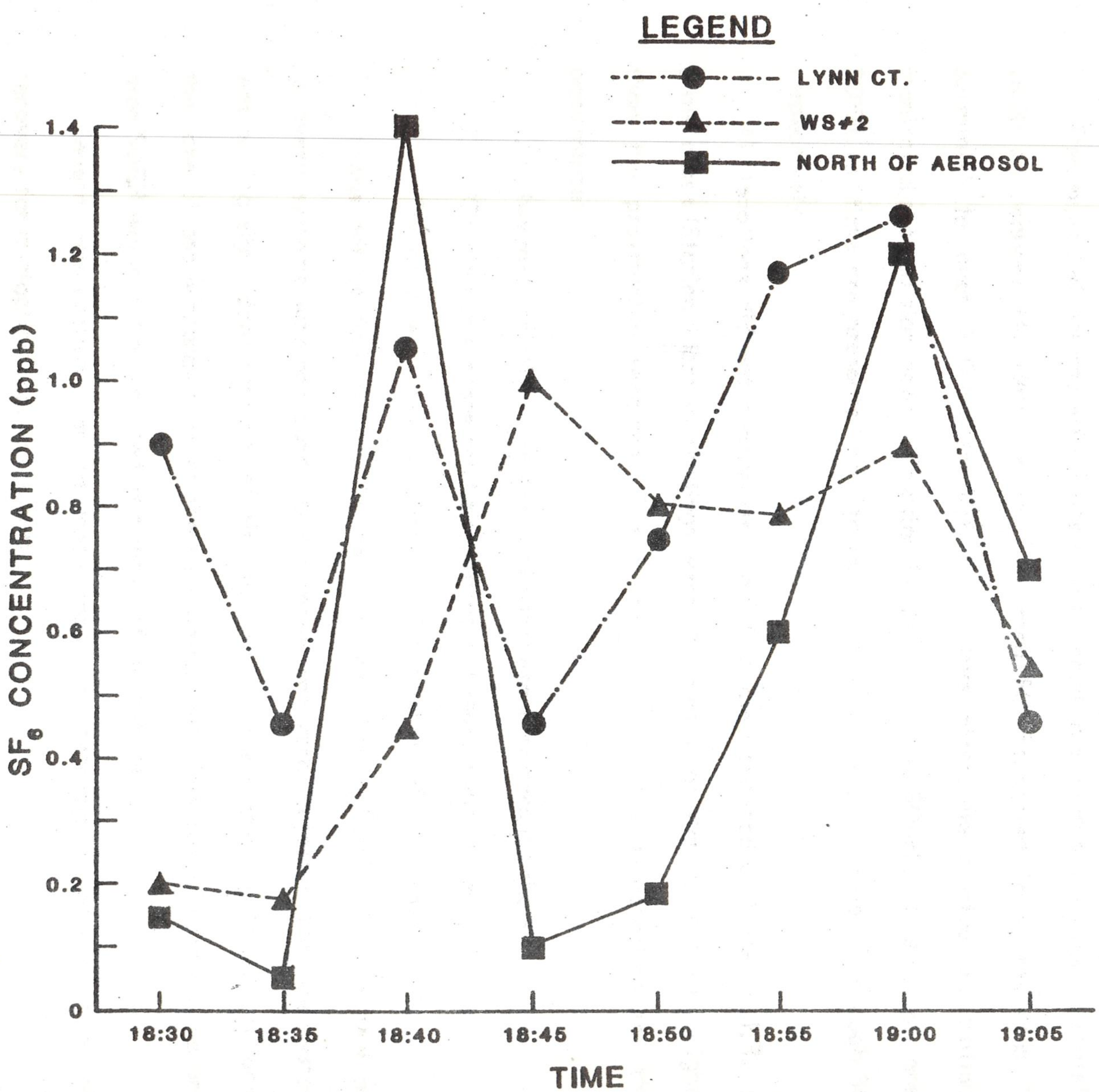

FIG. 28 TRACER CONCENTRATIONS VERSUS TIME FOR WEST WINDOW (1/21/81)

As indicated on Table 27, the water aerosol system did sometimes increase the RH of the air. As with the tracer, results were often erratic. Some measurements showed a definite increase in RH while others showed no increase. This could have been the result of erratic wind movements. The fact that RH was increased, even with high initial RH indicates that this system has potential for accomplishing the objective for increasing RH. The system should be even more effective when RH is initially low.

In the evaluation of micrometeorology it was noted that RH had increased in January over that which occurred in December. Occurring with the increase in RH was a decrease in the number of confirmed and measureable downwind odor conditions. The higher RH may be indicative of a decrease in inversion strength in January compared to December. Thus it may be that the water aerosol system could not produce significant changes in mixing because mixing conditions were already relatively good.

To the extent that the increased RH in January reduced the odor complaint conditions a water aerosol system which increases RH shows promise. A large scale water aerosol system warrants further evaluation at BKK under conditions of low RH to better determine its potential.

GAS RECOVERY EFFECTIVENESS

During the final week and a half of the baseline data collection period an expanded gas recovery system was placed into operation. An additional seven wells were drilled and connected to the existing centrifugal flowers and gas burners. The location of the new wells with the existing and proposed gas recovery wells is shown in Figure 29.

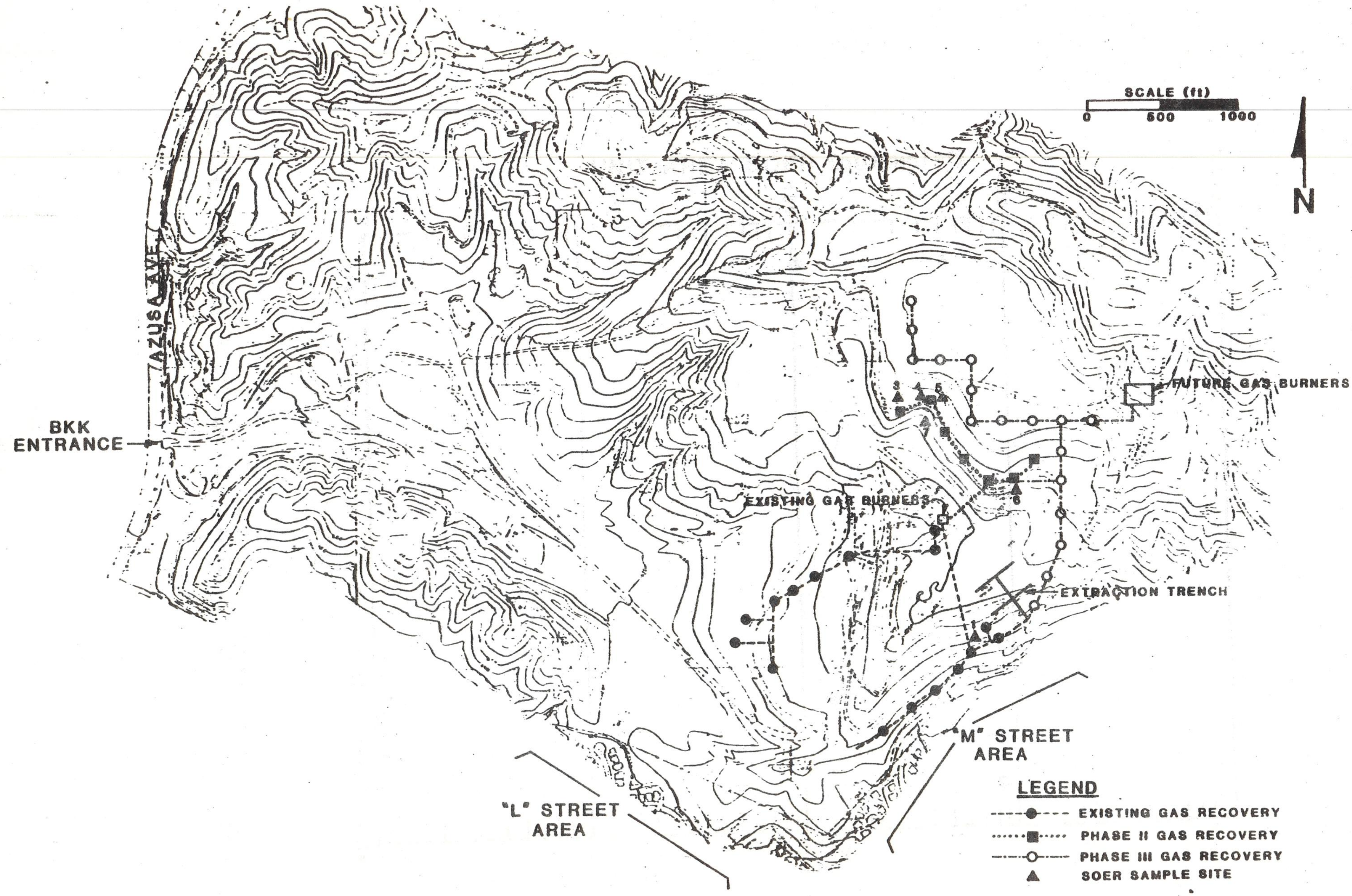

FIG. 29 BKK GAS RECOVERY SYSTEM

Seven unit area SOER monitoring locations were established in the vicinity of the new wells. These monitoring locations are also shown in Figure 29. Two locations were monitored prior to the gas recovery system startup while the remaining were monitored as the system started up. Results of the unit area SOER monitoring are presented in Table 28.

The expanded gas recovery system was placed into operation at approximately 16:00 on January 14, 1981. Initial unit area SOERs varied from less than 10 ou/min/sf to over 5,000 ou/min/sf. Two days after the startup all stations monitored showed significant reduction in their unit area SOER. Plots of unit area SOER vs. time are presented for Stations 1, 3, 4, 5 and 6 in Figure 30 through 34, respectively.

All locations did not continuously maintain their reduced unit area SOER. In some cases (Station 1 and 4) readings were obtained after startup that were higher than the pre-startup readings. There are many possible explanations for this occurrence:

1. Normal variation in strength of odors escaping through the soil.
2. Changes in surface conditions (cracks, fissures) with time.
3. The change is due to the varying effectiveness of gas recovery.

It was not possible to explain the variation. The efficiency of the new gas recovery systems was not good. Gas samples analyzed indicated that the system was pulling significant amounts of air. Air leaks in the system could have reduced the rate of gas withdrawal from the new wells. With less gas withdrawn, the unit area SOER would not be reduced as a result of gas recovery.

Several observations can be made about the potential effectiveness of gas recovery for mitigating odor emissions:

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TABLE 28

SUMMARY OF GAS RECOVERY SOER MEASUREMENTS

Date	Starting Time	Station #1	Station #3	Station #4	Station #5	Station #6	Station #7	Comments
		UNIT AREA SOER (ou/min/sf)						
1/8/82	18:55	104	52					
	20:45	521	52					
1/14/81	15:40		7	5208	5208	5208		Gas Recovery System placed in operation @ 1600, 1/14/81
	17:20		3					
	17:35		208					
1/16/81	17:10		10	417	35	7		
	21:05		2	104	104	104		
1/19/81	18:37	104	5	52	104	35		
	22:20		5	1042	104	5		
1/20/81	15:30	1042	4	104	26	21		
1/21/81	17:00	140	104	208	104	26	208	
	21:00		104	417	104	10	104	
1/22/81	21:30		5	6944	520	8		
1/23/81	16:05	868	5	651	651	10	260	Ground was wet after rain.

Note: Monitoring locations are identified on Figure 29.

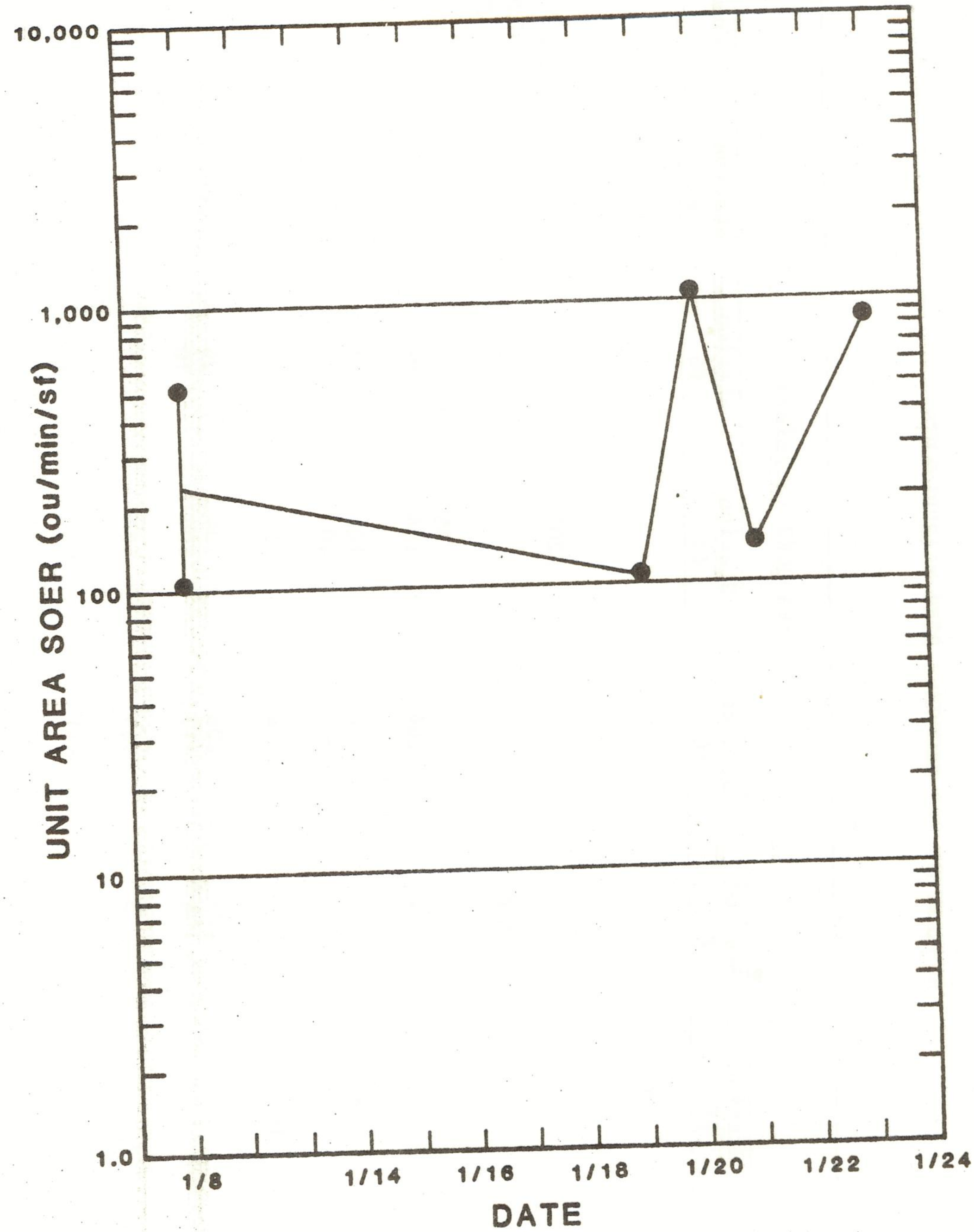

FIG. 30 SOER VERSUS TIME - STATION NO. 1

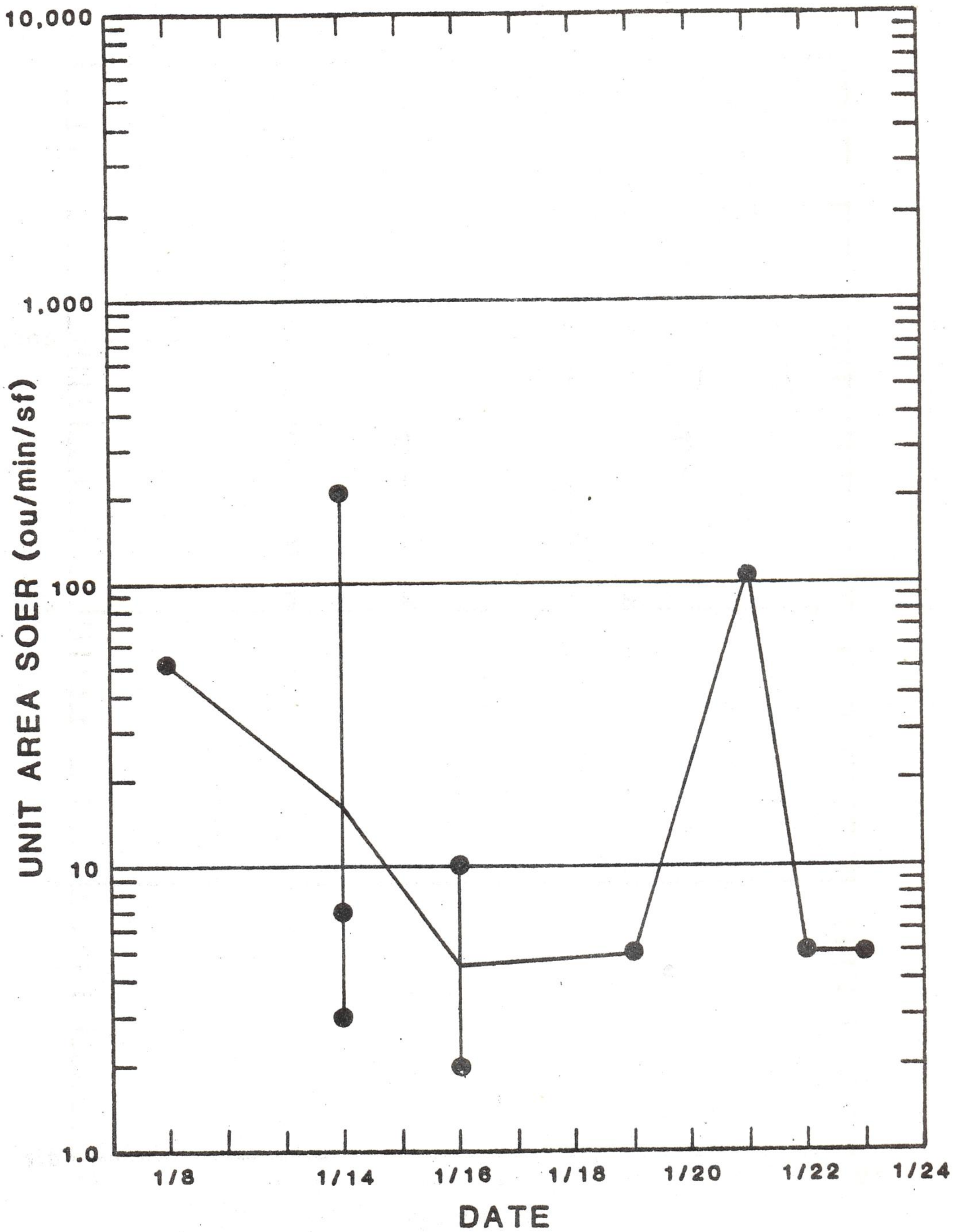

FIG. 31 SOER VERSUS TIME - STATION NO. 3

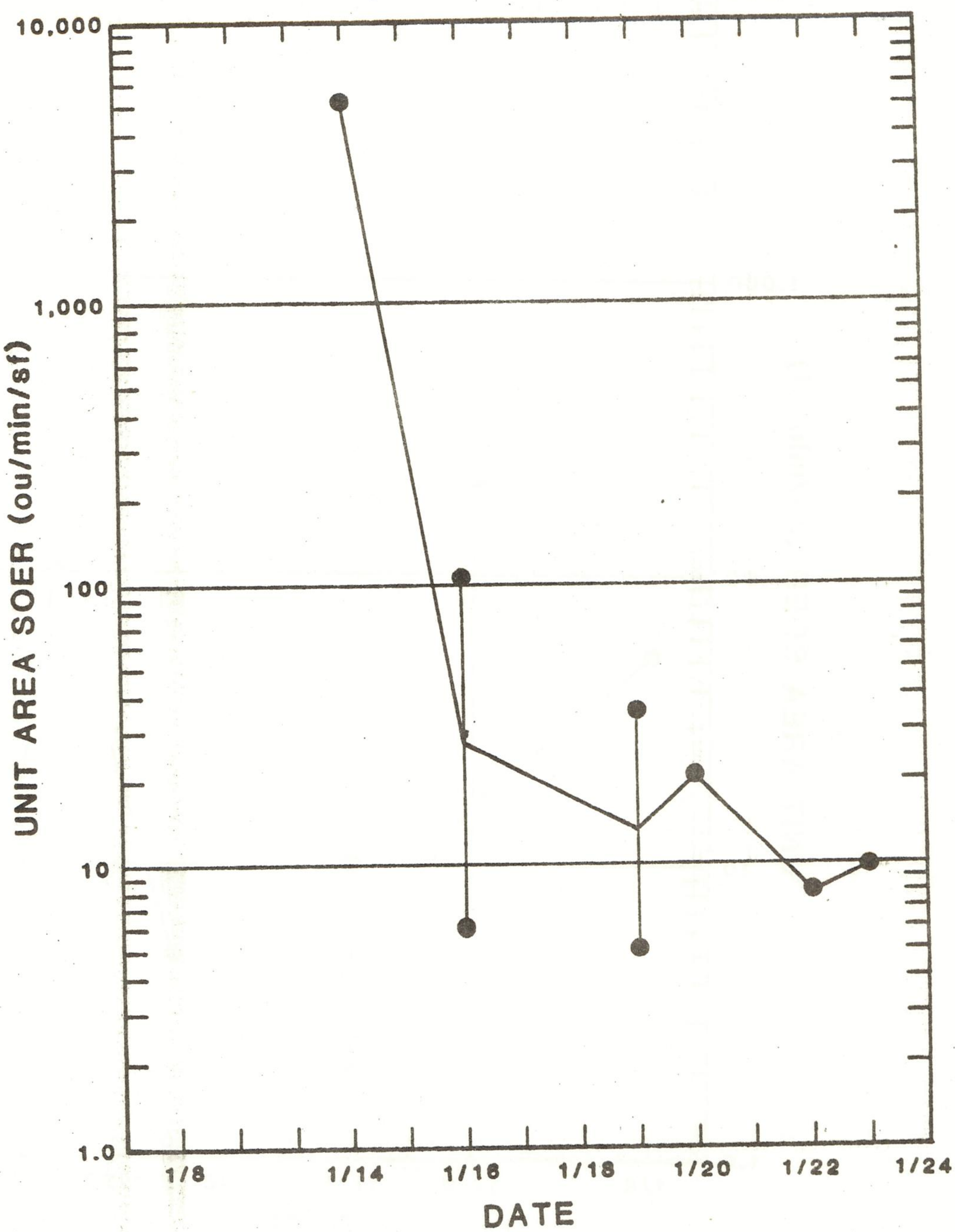

FIG. 32 SOER VERSUS TIME – STATION NO. 4

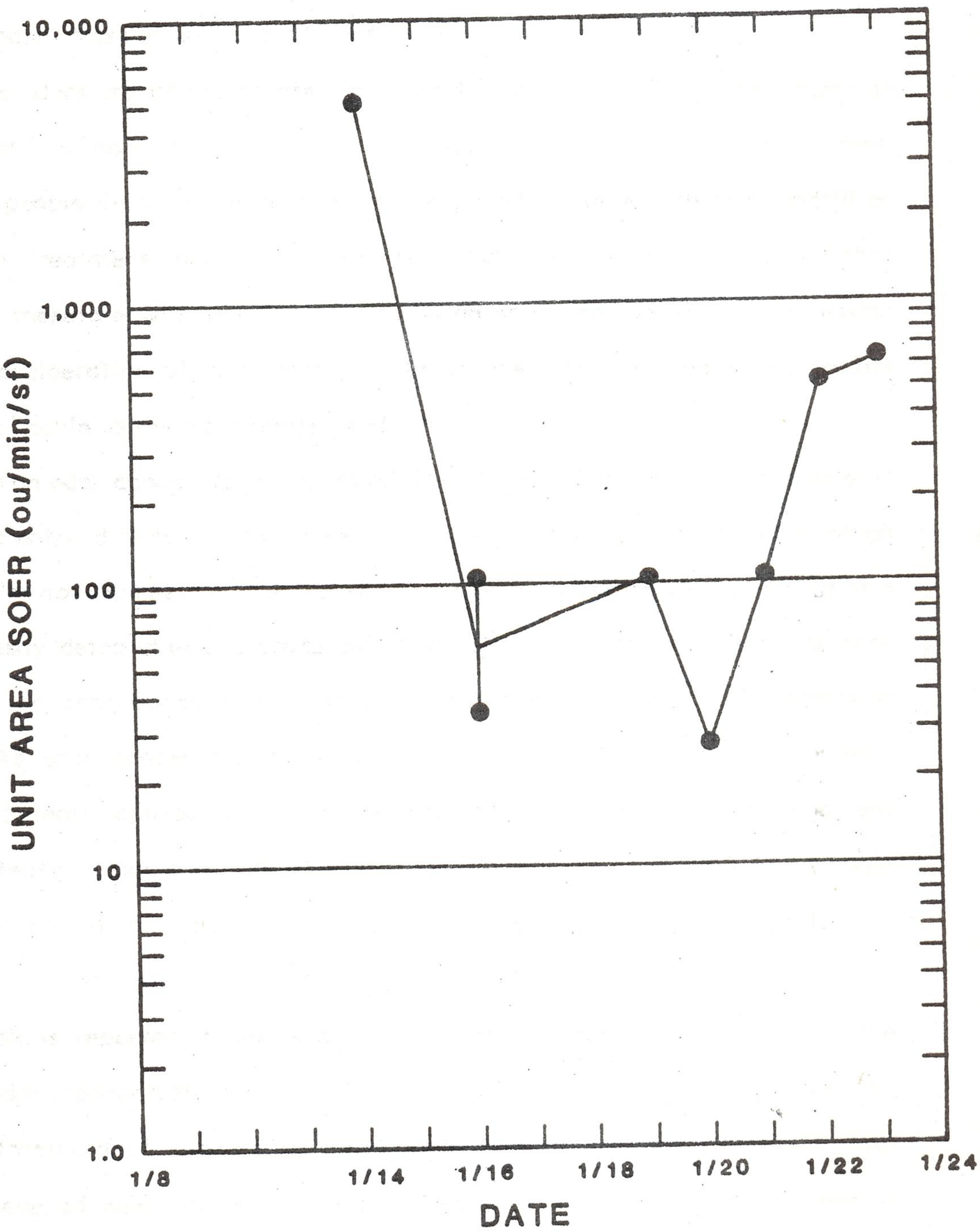

FIG. 33 SOER VERSUS TIME - STATION NO. 5

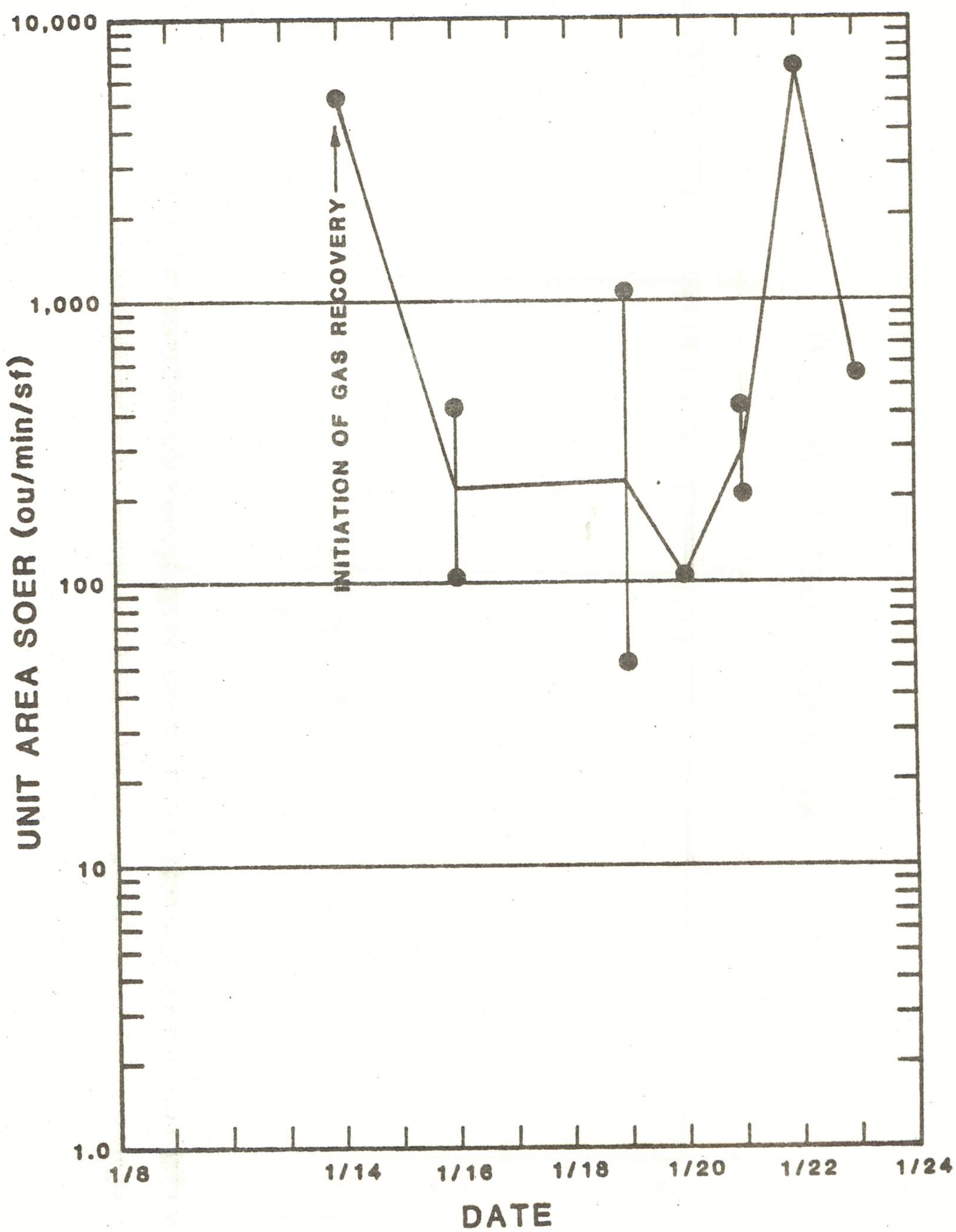

FIG. 34 SOER VERSUS TIME – STATION NO. 6

1. If all gas that is escaping through the soil is completely contained (prevented from surfacing) there should be a significant and documentable reduction in site odor emissions.
2. The effectiveness of gas recovery in reducing the unit are SOER has been shown to be variable.
3. All other things being equal, that variability may be due to variable effectiveness of the gas recovery system.

If gas recovery is to be an effective mitigation system for reducing site odor emissions, the system must be designed to insure that most if not all gas is recovered. System construction must be continous as the landfill is filled. The system must be closely monitored to insure that it is working properly. Carefull consideration should be given to the zone of influence and spacing of the wells. The system should be "balanced" so that each well can supply an equivalent amount of gas. The system may requires significant oversizing if all gas is to be recovered. The gas content should be continuously monitored to insure that there are no air leaks in the system.

ODOR RISK ASSESSMENT

Odor risk is defined as the number of annual occurrences of odor concentrations in excess of a specified level downwind of an odor source. Odor, in the context with which it is discussed in this report, is defined as a human response to changes in olfactory stimulation caused by an odorant or mixture of odorants. Odor can be measured in a number of ways, but the simplest and most objective means is to measure its detectability. Odor detectability is measured as the number of clean air dilutions required to reduce an odorous volume of air to its minimum detectable threshold odor concentration (MDTOC), as determined by a trained human subject.

The number of dilutions to the MDTOC is reported as the odor concentration and has the units of odor units per cubic foot (ou/cf).

Nuisance odors are of the greatest concern to the public. The measurement of odor detectability does not distinguish between pleasant and unpleasant odors. However, to people living in the vicinity of a major odor source such as a landfill or a wastewater treatment facility, any detectable odor will be associated with that facility, and therefore will be considered to be an objectionable odor. In assessing odor risk, consideration of only detectability of the odor will make the results generally applicable to the most sensitive of individuals.

Whereas an odor concentration at its MDTOC is by definition just detectable, it is not sufficiently distractive to cause or demand the conscious attention of an individual. Previous studies have established that odor concentrations in excess of 5 ou/cf are easily detectable and cause sufficient distraction to result in some odor complaints. An odor concentration of 5 ou/cf has been termed the distraction threshold. As odor concentrations increase to approximately 10 ou/cf, the odor becomes sufficiently distractive to require conscious attention of an individual and thus consistently results in the occurrence of odor complaints. An odor concentration of 10 ou/cf has been identified as the odor complaint concentration.

Odor Risk

Odor risk is reported in terms of the number of days annually in which the downwind odor concentrations at a specified distance will exceed either the distraction threshold of 5 ou/cf or the complaint concentration of 10 ou/cf. An acceptable level of odor risk is usually specified in terms of a specific number of days in which odor concentrations may exceed either the distraction threshold or the complaint concentration at the minimum downwind distance. Typically, an acceptable level of odor risk is agreed upon between the public surrounding the major odor source and the management of the facility. Typical acceptable levels of odor risk are in the range of 1 to 5 distraction threshold events annually.

Atmospheric Transport and Detection of Odors

Odor risk requires a source of odor emissions, transport of odorous air near the ground and the presence of an individual who can respond to the odor. The odor emissions from the BKK Landfill must be transported through the atmospheric sublayer near the ground. Under normal levels of odor emissions, it is usually necessary that restrictive or critical sublayer transport conditions prevail between the source and the downwind contact point for the detection of odors. Under conditions of extremely high odor emissions, it may not be necessary for critical transport conditions to prevail in order to detect odor downwind.

Critical transport conditions are micrometeorological conditions which result in minimum dispersion (downwind dilution) of source odor concentrations as they are transported. In general, critical conditions occur when there is a strong sublayer temperature inversion. A strong temperature inversion prevents odors from mixing vertically in the air. The odors are essentially trapped in a relatively shallow layer of the air. The condition in which there is an absence of vertical mixing with strong inversion has been termed Puff Transport (PT). At the BKK Landfill site, the most critical condition appears to be calms which allow the downslope drainage of odorous air. Calm conditions with the presence of a strong temperature inversion will result in maximum downwind odor concentrations.

PT conditions have been observed to occur when the temperature difference (Δ T) as measured between 25 feet and 5 feet above ground level exceed a critical value (ΔT_c) of 2^oF. These conditions typically occur and are associated with a nighttime counter radiation inversion.

A model of odor transport under PT conditions has been developed and has been verified under field conditions. The model was developed to predict an inverse square root decay of pollutants with distance as has been observed under PT conditions. The model relates the downwind concentration c (ou/cf), to the odor emission rate Q (ou/min), downwind distance x (ft), the PT diffusivity, K' (ft/min^2), and a characteristic puff width Y, (ft) as follows:

$$c = \frac{Q}{K'(Yx)^{1/2}} \qquad (1)$$

This transport model is utilized to predict downwind odor concentrations in odor risk assessment.

The final requirement for odor risk is that there must be a conscious (awake) individual present who is breathing outside ambient air who can respond to the presence of detectable odors. In general, the contact point factors require that ambient temperatures are high enough to allow the complainant to be comfortably involved in some outdoor activity or with direct access to outside air through open windows.

Odor Risk Model

A number of specific conditions must be met simultaneously before the downwind detection of odors is possible. The specific conditions relate to the magnitute of odor emissions and the site micrometeorology. The odor risk model requires that the following three specific conditions occur simultaneously:

1. Critical transport conditions.
2. Odor window.
3. Excess odor concentration.

Critical Transport Conditions. The first condition necessary for odor risk is a condition which will result in minimum downwind dispersion of odors. This can occur under PT or calm conditions. In the case of the BKK Landfill, critical transport has been observed to most frequently occur under calm conditions. The PT or calm condition must be of sufficient duration to allow time for the transport of odors to the specified downwind distance. For the BKK site odor risk assessment, critical transport conditions were defined as either PT or calm conditions which last for a minimum of one hour during the normal waking hours of 0600 to 2300. The time of day restriction was included to provide reasonable assurance that individuals will be awake and capable of responding.

Odor Window. Odor detection occurs when odorous air comes in contact with a conscious individual. In order for a contact to occur the outdoor ambient air must have relatively direct access to an individuals nose. An open window or outdoor activity will insure a potential response. Time and circumstances under which an individual can detect and respond to odors has been termed the "odor window". The odor window concept simply requires that ambient temperatures be between 60°F and 90°F during a PT or calm condition. When temperatures are below 60°F, outdoor activities are limited and windows are likely to be closed. When temperatures are above 90°F, windows are likely to be closed due to the use of air conditioners.

Excess Odor Concentrations. Excess odor concentrations occur during critical transport conditions when source odor emission rates and the prevailing atmospheric dispersion result in downwind odor concentrations (c) in excess of the specified concentration (c_s). Excess odor concentrations are determined with the PT dispersion model, equation (1). An excess odor concentration will occur for PT conditions whenever

$$\frac{Q}{K'(Y)^{1/2}} = c_s(x)^{1/2} \qquad (2)$$

The frequency with which equation 2 is satisfied can be determined statistically using independent cumulative frequency distributions for Q and $K'(Y)^{1/2}$.

Assessment of Odor Risk

An assessment and prediction of odor risk is possible through a program that is designed to determine the frequency of occurrence of each of the requirements for odor risk as previously discussed. Due to seasonal variations in site micrometeorology, the accurate prediction of odor risk requires monitoring of odor emissions from each landfill odor source and a minimum one year micrometeorlogical data base.

Computation of Odor Risk. The three general requirements for the assessment of odor risk are combined to determine the annual number of odor risk events, $N (c \geq c_s)$ as follows:

$$N (c \geq c_s) = 365 \Sigma f_i D_i B_i \Gamma \qquad (3)$$

Where,

N = number of odor risk events

c = downwind odor concentration

c_s = specified downwind odor concentration

i = time interval of year

f = frequency of time interval where $\Sigma f_i = 1$,

D = odor window frequency

B = frequency of critical transport events

Γ = frequency of $c \geq c_s$ given critical transport event

Equation (3) assumes independence of each variable. A discussion and justification for the independence assumption is included in Reference (2).

Odor Risk for BKK Landfill site.

Projected Total Site Odor Emissions. The estimated frequency distribution for the total site odor emissions was presented on Figure 23. Odor risk was computed assuming odor emissions at the December levels and at reductions of 90% and 99%. It was estimated that the December median level of odor emissions was approximately 48×10^6 ou/min. A 90% reduction would reduce the median site odor emission rate to 4.8×10^6 ou/min. A 99% reduction would reduce the median odor emission rate to 0.48 x 10^6 ou/min. The 90% and 99% reductions in surface odor emission rates are assumed to retain the same frequency distribution slope as at present.

Projected Frequency for Critical Atmospheric Conditions. Based on measurements completed at the BKK Landfill site, calm conditions have occurred on approximately 90% of the days studied. The months of December and January generally represent the highest frequency of critical atmospheric conditions. For the odor risk projection the frequency of critical transport conditions (B) was taken as the frequency of calm conditions for December and January. This should produce conservative results.

Projected Frequency of the Odor Window. During the months of December, 1980 and January, 1981, maximum daily temperatures have been between 60°F and 90°F. Since the months of December and January are generally the coolest months of the year, and since temperatures were always sufficiently warm to allow for both outdoor activities and open windows, it has been assumed that the odor window frequency for the West Covina area is 1.0.

For many climates, the odor window frequency during the months of December and January is close to zero. Thus, the mild climate of Southern California contributes to the severity of the problem because direct exposure to potentially odorous air is increased.

Projected Frequency of Excess Odor Concentrations given Critical Transport Conditions. The occurrence of the critical transport condition in combination with the odor window does not necessarily mean that downwind odor concentrations will exceed those specified. The total site odor emissions are assumed to take on a log normal probability distribution (Figure 23). The magnitude of dispersion that will occur under given PT conditions is also expected to assume a log normal probability distribution (Figure 21).

Given critical transport conditions, the combined effect of odor emission rate and available atmospheric dispersion will determine whether excess odor concentrations will be detected at the specified point downwind. Statistical procedures were utilized to determine the frequency of excess odor concentrations given frequency distributions of the total site odor emissions and the PT diffusivity. The statistical methods are documented in Reference 2.

Frequency of Wind Direction. Under non-calm conditions, the wind direction frequency will determine the frequency of exposure to odors that various downwind sectors will experience from the BKK Landfill site. The odor risk, as viewed from a downwind resident, will be only a small fraction of the total odor risk for the site. Residents living to the north of the BKK Landfill and on the west side of Azusa Avenue will probably only experience odors from the landfill when wind is directionally aligned with their residences and measurable wind speeds prevail. For residents living in the M and L Street areas, odor risk can occur during calm conditions. Their degree of exposure is not dependent entirely upon wind direction but is more dependent upon the presence or absence of calm conditions. It is under the calm conditions that the downslope drainage of air from the landfill to these areas will prevail.

Downwind Distance. Downwind distance chosen for the assessment of odor risk was 2,000 feet. This distance was representative of the average distance from the central part of the landfill to the nearest downwind residences.

Specified Odor Concentrations. The specified odor concentrations for the odor risk assessment were the 5 ou/cf distraction threshold concentration and the 10 ou/cf complaint concentration.

Odor Window Event Frequency. The odor window event frequency has been assumed to be equal to 1.0. The projected frequency of the odor window events is based on monitoring of temperature data during the month of December 1980 and January 1981. The use of an odor window event frequency of 1.0 should produce conservative results.

Projected Odor Risk

The projected annual odor risk for the BKK Landfill site has been presented on Table 29. Under the December levels of odor emissions it is estimated that odor risk will occur on approximately 188 days per year or equivalent to about one-half of the days in the year. During the 1979 and 1980 years, odor complaints occured on approximately 2/3rds of the days annually.

A 90% reduction in odor emissions would reduce the level of odor risk events to 10% of the existing value or approximately 19 days per year. A 99% reduction in odor emissions would reduce odor risk events to approximately 2 days per year.

Uncertainty Analysis

The entire odor risk assessment has been based on a number of assumptions which have been explained in this report. Attempts have been made to project conservative results. The odor risk computed here is for normal conditions of landfill operations. Odor risk will greatly exceed that projected if abnormal conditions prevail such as pipeline breaks, etc.

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TABLE 29

ESTIMATED BKK LANDFILL ODOR RISK

Condition	Odor Risk[1] 5 ou/cf	10 ou/cf
Existing[2]	188	139
90% Reduction in Odor Emissions	19	14
99% Reduction in Odor Emissions	2	1.4

(1) Number of days per year at a distance of 2000 ft. downwind of the landfill.

(2) Based on December 1980 Odor Emission Rate

The assessment of odor risk is only as strong as the data base from which it is derived. Because the data base was necessarily limited in time, risk projections based on two months data may not apply to the balance of the year. This weakness has been mitigated, by using conservative assumptions in predicting risk. Conditions should be better than those predicted.

VI. POTENTIAL OF ALTERNATIVE MITIGATION MEASURES

Alternative odor mitigation measures will be discussed under the categories of source controls and large area controls.

SOURCE CONTROLS

Neutralization of Acids

The disposal of acid wastes at the BKK Landfill was identified in the USC study as being a major contributor of odors (1). Acid disposal was eliminated at the BKK Landfill prior to December 1. Acid wastes are now either neutralized prior to transport to the BKK site or are redirected to other legal landfills. It has not been possible to directly measure the significance of this change in practice in reducing the BKK Landfill odors because these actions were taken prior to the initiation of the EUTEK study.

However, a trend indicating reduced downwind odor conditions from the site has been noted from January observations relative to those in December. This trend, indicating an apparent reduction of 73%, has been discussed in Chapter V. This reduction may be due in part to a reduction in site odor emissions as a direct or indirect result of the elimination of acid disposal. At this time it is impossible to determine the benefit of this action.

Timing of Daily Operations

The onset of critical transport conditions at the BKK site occur at approximately sundown. During winter, the onset of critical transport conditions occurs nearly simultaneously with the closing of the working face. Some odor complaints have occurred in the early evening hours (prior to 6 p.m.) before the closing of the working face. Based on their frequency it is estimated that less than

10 to 20% of odor complaints result from landfill operations on the working face. Thus, changes in timing of daily operations would not greatly reduce the severity of the odor problem at the landfill.

Gas Recovery

Expansion of the gas recovery system appears to have good potential for reducing downwind odor concentrations if carried out efficiently. To the extent that expanding the gas recovery system can prevent the escape of landfill gas through the soil it should reduce odor concentrations proportionately.

Prior to January 14th, the gas recovery system had the capability of extracting approximately 2200 cfm of gas. BKK has estimated that the total gas production at the site was 6600 cfm. Approximately 4400 cfm of landfill gas is escaping through the soil into the atmosphere. Equipment has been ordered which should increase the capability to extract and incinerate landfill gas to 5200 cfm by June 30, 1981. Ultimately, an additional 9 gas extraction wells will be installed as a part of a U.S. Department of Energy feasibility study grant which would expand the gas extraction capability to 7200 cfm.

Combustion of the landfill gas reduced the gas odor concentration approximately 99.9%. If the ultimate gas extraction system is successful in preventing the escape of odorous landfill gas through the soil, a satisfactory reduction in the site odor risk could be expected.

LARGE AREA CONTROLS

Barriers

Barriers have the potential for mitigating the BKK site odor problems in two ways. The first is the use of barriers as a vertical mixing device under conditions of winds greater than 2 mph.

The absence of mixing winds and low RH at the BKK Landfill could be mitigated through use of wind machines and water aerosol subject to satisfactory sound barriers. In combination with these systems, barriers could reduce the required gas recovery effectiveness to 1/3 to 1/2 of present estimates.

The second use of barriers is in conjunction with land contouring and/or construction of levees for channeling and redirecting flow. Barriers and levees do act as effective dams for cold air. The effectiveness of the barriers for channeling and redirecting air flows should be field evaluated.

It was noted both in the routine odor patrol surveys and in the analysis of odor complaints that few complaints originated from the 'N' Street area. The N Street area is immediately to the west of the 'L' Street area but is separated from the landfill by a large hill. Cool air draining off the landfill will either flow towards Azusa Avenue near the BKK entrance or will flow out the West Window into the L Street. It appears that relatively few complaints occur in the N Street area because of its relatively high elevation and the protection by the hill. It may be possible to protect the L Street area in a similar fashion.

The watershed drainage areas of the BKK Landfill are shown on Figure 35. Under calm conditions with no external forces except gravity, air would be expected to drain downhill as it cools. Whereas the only significant force acting on water is gravity, air with the action of upper wind movement and momentum has external forces that can overcome the effects of gravity. The result is that under calm wind conditions air can move uphill where the slope is not too steep.

An examination of the landfill site topography shows that much of the landfill area (upper and mid-decks) could drain into the M Street area. Similarly, with the exception of the slopes facing the M Streets, the entire landfill area could drain

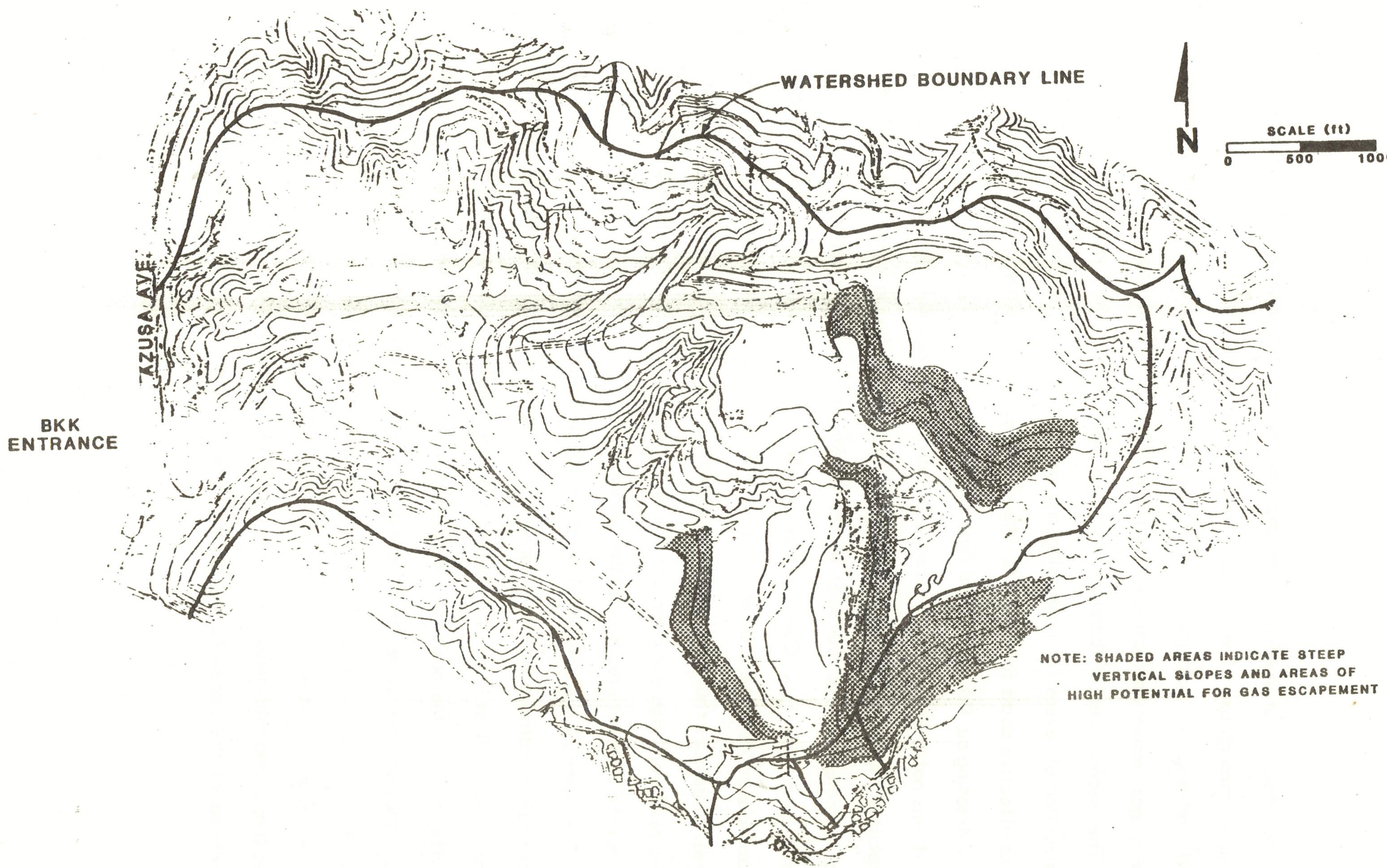

FIG. 35 BKK LANDFILL WATERSHEDS

into the L Streets. Normal drainage without external forces for the majority of the landfill area would be towards Azusa Avenue near the BKK entrance. The slopes above the M Street area are the only part of the landfill which naturally drains away from Azusa Avenue. Observations of smoke following the natural water drainage paths have been made. These observations suggest that air drainage under calm conditions could be modified by building slopes and/or barriers to isolate residential areas from the landfill. This could help reduce odor risk.

If an earth embankment were constructed across the West Window, it should be possible to redirect the cold air flow and prevent much of the L Street odor risks. The objective would be to isolate the L Street area from the landfill by eliminating the West Window as a point of drainage of cold air from the landfill.

It may also be possible to isolate the M Street area from approximately 80% of the landfill area. It would be virtually impossible to isolate the M Street area from the existing terraces and slopes facing the M Street area. However, it may be possible to isolate this area from much of the landfill by providing earthen berms along the outside edges of the working decks. The current operation plan requires that ultimately 15 ft. horizontal of compacted earthfill be placed on the finished slopes of the Landfill. A perimeter berm could be constructed on the M Street side of the working decks prior to the placement of solid wastes on those decks. The berm would ultimately be utilized as the 15 ft. final fill. As solid waste is placed against the berm on the working decks, a new berm would be constructed directly above it. The desired effect would be to continually isolate the majority of the landfill area from the M Streets. The objective of the berms would be to redirect downslope drainage away from the M Street area. The proposed concept of utilizing berms on the M Street slopes is illustrated on Figure 36.

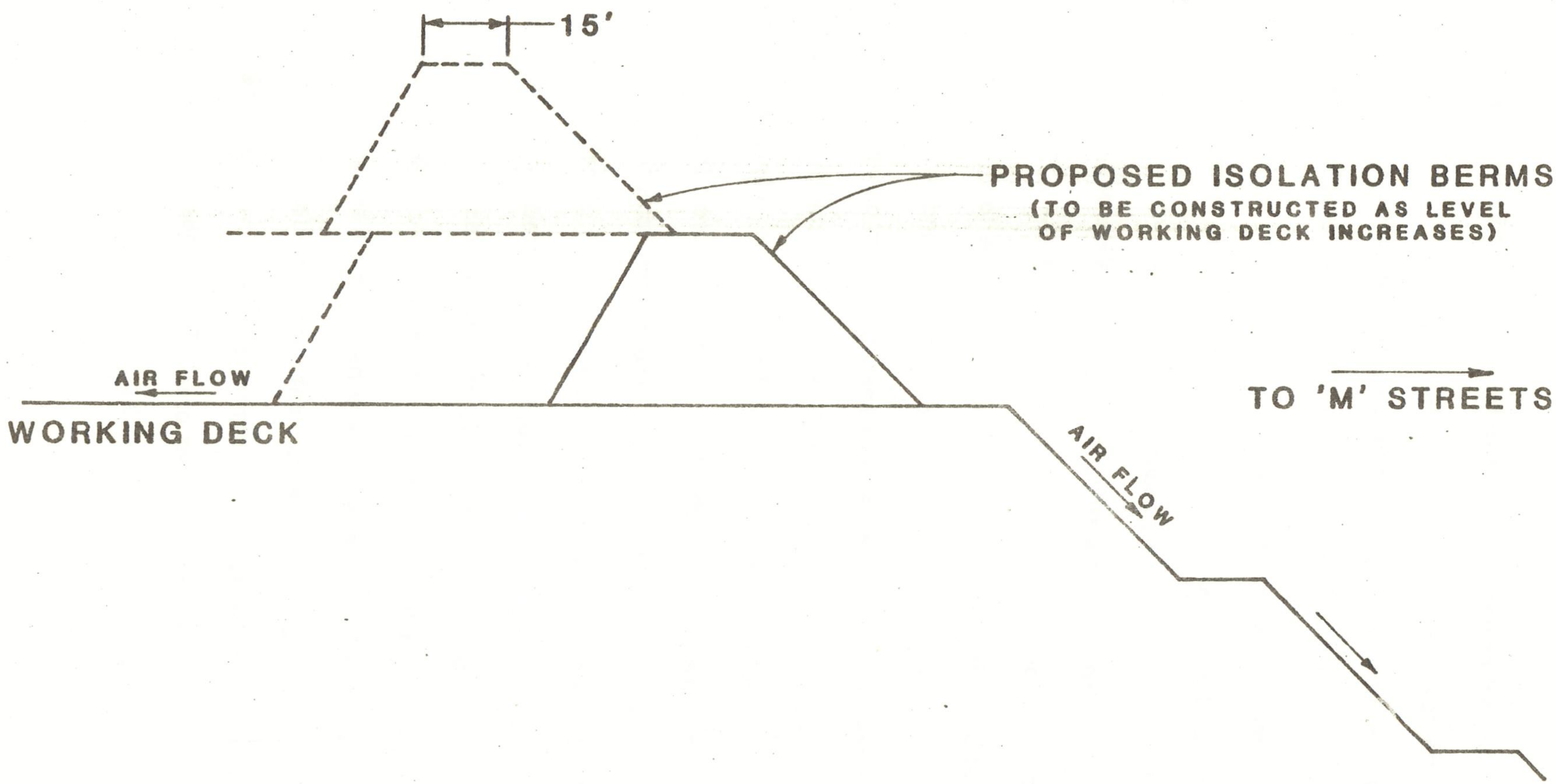

FIG. 36 PROPOSED BERMS FOR 'M' STREET AREA

Only those odors which are released on the finished terraces below the berm could flow to the M Street area. Control of odor emissions from these finished slopes would have to occur entirely by gas extraction wells.

Water Aerosol

Even under the high ambient RH conditions during evaluation of the water aerosol system, increases in RH were noted to occur. These increases could be expected to be greater under low RH conditions.

The higher ambient RH conditions which occurred during January could partially explain the observed reduction in the number confirmed and measureable odor complaints. Artificially raising RH with a water aerosol system under otherwise low RH conditions could have a similar effect on reducing the frequency of downwind odor complaint conditions. Evaluation of the effectiveness of a large scale water aerosol system for raising RH should be considered.

POTENTIAL EFFECTIVENESS OF SELECTED MITIGATION MEASURES

Based on the BKK Corporation estimates of the present gas production rates at the landfill site, it is estimated that by June 30, 1981, odor emissions from the site can be reduced by up to 68% by gas recovery. An earthen berm closing the West Window to downslope drainage cold air has the potential to reduce the frequency of total site odor complaint conditions by an estimated 22%. Redirecting and channeling cold air downslope drainage above the M Street area has the potential to reduce total odor complaints conditions from this area by up to 80%. Since this area has accounted for 67% of total odor complaints from the site, overall reduction would be 54%.

The potential combined effect of implementing all of these independent mitigation measures would result in a residual odor risk of,

$$(1 - 0.68)(1 - 0.22)(1 - 0.54) = 0.11$$

or, an overall reduction of 89%.

The control measures which BKK Corporation has already implemented have been partially responsible for reduction in the downwind odor conditions as measured in January relative to those measured in December by 73%. This trend may continue. If it is assumed that no further changes occur, the resultant residual odor risk with all of the above listed mitigation measures relative to the calculated December risk would be,

$$(0.11)(1 - .73) = 0.030$$

This represents potential overall reduction of 97% or a projected frequency of 5 ou/cf of 6 events per year and a 10 ou/cf annual event frequency of 4. With implementation of additional gas recovery, a further reduction in odor risk should occur to a level of less than five 5 ou/cf events per year. Under these conditions the BKK Class I Landfill should become a good neighbor to surrounding residents.

RAMIFICATIONS OF LANDFILL CLOSURE

Closure of the BKK Landfill is an alternative being urged by some West Covina citizens. When considered as an odor mitigation measure, this alternative proves to be ineffective. Closure of the BKK Landfill at this time would accomplish one thing in the way of odor mitigation. Ten to 20% of the odor complaints have been attributed to the working face during daylight hours. Closure of the landfill would eliminate the working face and would thereby reduce odor risk by approximately 10 to 20%.

There would, however, be concomitant events occurring with landfill closure which could be counter-productive from the standpoint of reducing odor emissions. Cracks and fissures in the landfill surface cover could be expected to increase with time and with lack of continual maintenance. This would result in greater releases of landfill gases which have not received the benefit of filtration through a closed soil surface. There is as well the problem of maintaining a continuous and effective gas recovery system at a closed facility.

As has been noted in the previous section, almost 90% reduction in odor emission can potentially occur as the result of the planned expansion in gas recovery systems at the BKK Landfill in conjunction with measures to redirect and channel cold air downslope drainage to prevent access to the L and M Street areas. The measures that the landfill is currently taking to restrict its acceptance of acidic wastes and highly odorous wastes appear in part to be reducing the magnitude of site odor emissions. If the site were closed, expansion of the gas recovery system would not occur and the correct and appropriate configuation of the landfill slopes to prevent access of odorous cold air downslope drainage to the L and M Street areas could not occur. Thus, site closure would not accomplish the degree of potential reduction in odor risk which would be accomplished with continued operation of the site with implementation of the selected odor mitigation measures.

In conclusion, it must be borne in mind that the primary source of odors from the BKK Landfill is landfill gases escaping from the surface of the site. These gases are being generated beneath the surface by microbiological activity which will not cease with the closure of the landfill. In fact, this activity can be expected to continue for years. The most effective way to reduce the odor risk associated with the site under these circumstances is to implement intelligently selected mitigation measures to both reduce the likelihood of gases escaping from the surface of the landfill and reducing the likelihood that any such escaped gases will reach residential areas in detectable concentrations.

VII. CONCLUSIONS AND RECOMMENDATIONS

In this chapter overall study conclusions have been presented with recommendations on future actions by both the City of West Covina and BKK Corporation relative to the future operation of the landfill. Areas where uncertainty exists or where further study is warranted are discussed.

CONCLUSIONS

The following were the key findings of the BKK Landfill Odor Study:

1. Odor complaint conditions frequently occur in the vicinity of the BKK Landfill due to the Landfill. The occurrence of complaint level odor concentrations was scientifically verified.
2. Historical odor complaint analysis suggests that site micrometeorology is a key factor in the distribution and frequency of occurrence of the odor complaints. The existence of ground level radiation inversions and calms appear to be critical to the transport of odors downwind.
3. The most seriously affected residential areas are the "M" Streets and the "L" Streets. These residential areas are downslope of the landfill. By comparison, the occurrence of complaints in other areas is infrequent.
4. Complaints occur as frequently on Sunday when the landfill is closed as they do during days of operation. Odor complaints occur most frequently after the landfill is closed and the working face is covered. This suggests that gas migration and the subsequent surfacing of gas is the probable source of most complaints.

5. The raw landfill gas generated by microbiological action is extremely odorous. Soil filtration is effective in reducing, but not eliminating landfill gas odors. The migrating gas surfaces randomly throughout the landfill area. The location of surfacing landfill gas changes frequently. The concentration of odors emitted from the surface varies widely.

6. Combustion of landfill gas is very effective for the reduction of odors. Odor concentrations were reduced 99.9% with combustion.

7. Micrometeorological monitoring at the BKK Landfill site verified that extremely stable meteorological conditions can prevail. Wind is frequently calm during nighttime hours. Sublayer temperature inversions occur frequently. The calm condition with a sublayer temperature inversion will allow the downslope drainage of cool air. The phenomena of downslope drainage was verified with smoke visualization studies and with temperature measurements. Odors were most frequently noted in low, cold air spots.

8. The most frequently occurring mechanism of odor transport is the downslope movement of cool air during the evening hours under calm conditions. The cool air picks up odors migrating through the soil with the landfill gas. The odorous air moves downwind without significant vertical mixing. The absence of turbulent mixing results in high odor concentrations being carried to the nearby residences.

9. A reduction in the frequency of confirmed and measurable downwind odor conditions occurred in January relative to December. The reduction in

downwind odor conditions was the result of reduced site odor emissions and increased RH. The reduced site odor emissions were probably a result of action taken by BKK Corporation. RH was significantly higher in January relative to December. This fact raises the possibility that at least part of the reduction in downwind odor conditions was the result of less critical atmospheric conditions. The overall effect of the reduction in site odor emissions and increase in RH was a reduction in site odor emissions equal to 73%.

10. The site odor emission rate as it existed in December and January produced unacceptable odor risk. It was estimated that an equivalent reduction in site odor emissions of about 97% from December levels would result in an acceptable level of odor risk of less than five 5 ou/cf events annually. The equivalent reduction could be attained through a combination of source and large area controls.

11. Under the prevalent calm conditions the barrier acted as a cold air dam. The absence of wind speeds in excess of 2 mph prevented the evaluation of barriers is a mixing device. The observation that barriers act as cold air dams suggests that barriers with earthen levees could be used to channel or redirect downslope drainage of cold air.

12. The water aerosol system was sometimes effective in increasing RH under the prevalent evaluation condition of calm air with high RH. Under conditions of lower RH the system may be more effective. The potential of this large area emission mitigation measure should be evaluated on a larger scale under low RH conditions.

13. The gas recovery system evaluation indicated that the effectiveness of gas recovery in reducing surface odor emissions depends on the efficiency of recovery. An initial reduction was observed followed by sporadic increases. The increases may have been the result of poor recovery efficiency. With an effective system (all gas recovered) reductions in site odor emissions should be substantial.

14. A combination of mitigation measures including full gas recovery, and construction of berms and barriers for effectively redirecting and channeling cold air flow have the potential for an equivalent reduction in site odor emissions of greater than 97%. This reduction would bring odor risk to an acceptable magnitude.

RECOMMENDATIONS

The following recommended program can ultimately lead to a successful resolution of odor problems in the vicinity of the BKK Landfill. Recommended actions and follow-up studies are discussed. The recommendations are intended to be applied sequentially with follow-up evaluation of effectiveness. The sequence of the recommendations is intended to result in minimum disruption of normal landfill operations.

Continue Operational Controls

1. Continue all ongoing filling, grooming and maintenance of landfill slopes.
2. Continue to reject odorous substances that would otherwise be landfilled at the BKK site.

Implement Effective Gas Recovery As Planned

1. Immediately implement a full gas recovery system. Determine the effectiveness of the full gas recovery system in a follow-up odor study. This recommendation should be top priority and should be fully evaluated and implemented prior to implementation of other measures.

Design And Construct Earthen Levees With Barriers To Channel And Redirect Cold Downslope Drainage Air

1. Evaluate the effectiveness of berms and barriers for channeling and redirecting cold downslope air flow. This evaluation would follow construction of a portion of the system. Criteria for the ultimate berm and barrier system would be developed during the evaluation.
2. Build berms to isolate the L and M Street areas from the landfill. The L Street berm should close the west window. The M Street berm should isolate the top and middle deck from the M Street area. The M Street berm should be incorporated as a part of the final fill on the finished slopes.

Design And Construct Peripheral Water Aerosol System To Significantly Increase Relative Humidity Of Downslope Drainage Air

1. Evaluate the effectiveness of a large scale water aerosol system on the downslope periphery of the landfill to increase relative humidity of downslope drainage air and reduce the counter radiation causing "puff transport" conditions. Develop design criteria for complete water aerosol system.
2. Install complete water aerosol system to significantly increase relative humidity of all air passing from landfill to downslope residential areas.

Evaluate And Install Micrometerological Controlled Wind Machines Along Periphery of Landfill

1. If the above measures do not produce satisfactory results, evaluate the effectiveness of wind machines used in conjunction with barriers and water aerosol to increase mixing. Determine if the potential noise problem of the wind machines can be satisfactorily mitigated through the use of noise barriers.

2. Install micrometeorological controlled wind machines to effectively mix stable air under calm conditions.

REFERENCES

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5. Personal Communication with Jess Adams, California State Solid Waste Management Board, Tuesday, 20 January 1981.